THE Nation

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ATOMS for PEACE

SPECIAL 90th ANNIVERSARY ISSUE

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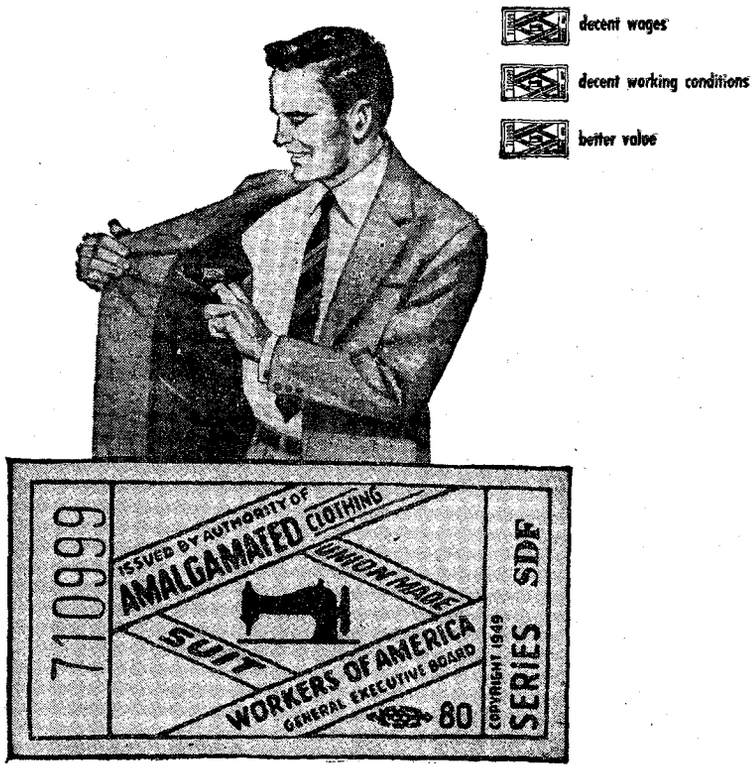

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THE Nation

EVERY WEEK SINCE 1865

1865 — 1955 . . by Freda Kirchwey

NINETY years ago *The Nation* was born in the backwash of the most terrible war this country had fought—a war that Charles A. Beard was to label the Second American Revolution. It was precisely that. It had freed four million black slaves—a change of revolutionary dimensions itself—and in the process had crystallized a much greater change already under way: the rise of financial-industrial interests which in a generation would remake the culture, politics, social life, and even the face of America.

Today *The Nation* celebrates its anniversary in the backwash of a much more terrible war, probably the last that civilization will succeed in surviving. Future historians may conclude that World War II was an extension, on a global scale, of the revolution ushered in by the War Between the States, but its magnitude is of a different order, and the process of radical change it has set in motion will remake not a nation but a world.

This birthday issue is going to deal with the threat and promise of that looming change. But before moving into the revolutionary future, it may be worth while taking a look at its modest nineteenth-century version. What did the editors of *The Nation* see as they sat down to put together Vol. I—No. 1? To judge by page 1, they saw little to worry them. The first editorial note began: "The week has been singularly barren of exciting events." The second referred briefly to the Negro's rise to prominence in the political arena. The third began, "The news from Europe is unimportant," and went on to deplore the impertinence of certain writers in England who presumed to tell us how to treat the defeated rebel leaders.

But the rest of the issue reflected clearly *The Nation's* chief concern as its life began: the complex problem of human rights created by the liberation of the slaves and the equally pressing one of restoring order and unity to the battered, still divided Republic. In spite of their passionate satisfaction over the outcome of the war, the editors obviously knew that victory had not brought peace or freedom but only the opportunity to try to establish them.

Turn of an Era

In any case Edwin L. Godkin and his associate editor, Wendell Phillips Garrison, could not have been expected to foresee the larger consequences of the war. No one could have imagined in advance the revolutionary impact on American life of machine power applied to a continent packed with natural wealth—much of it still undiscovered. Ahead lay the thrust of railways to the Pacific; the headlong exploitation of coal and iron, gold and copper, timber and—above all—oil in the not yet accessible Western lands. Ahead also was the growth of a new large-scale agriculture based on the homestead rather than the plantation. And still farther off, just out of range of the 1865 *Nation*, was the swift, ruthless consolidation of power by men, a mere handful actually, who employed a combination of brains and unmatched freedom from scruple to grab every possible strong point in the spreading empire of business. In the last thirty years of the century these men, the Robber Barons of Josephson's classic definition, ruled the government almost as despotically as they ruled their industrial domains. They were Capitalism, triumphant and hard, straight out of an old-fashioned Socialist cartoon; and while they developed a continent, they also raped it and corrupted its institutions. They owned the state legislatures. The press was largely theirs. They controlled most of the pulpits too. Business chicanery on a grand scale and the spoils system in government were their weapons; the Republican tariff was their stout barricade against competition.

Beside this Goliath *The Nation* was a very small David. Although primarily concerned with the issues of post-war reconstruction and civil rights, Godkin and his colleagues attacked strongly the corruption mounting throughout the Johnson and Grant administrations. The full significance of the rise of the business dynasties became evident more gradually, even though several of the great fortunes of the coming years had originated in army contracts and other Civil War sources of easy money. As big business gained power and wealth and numbers, and its methods were more openly displayed, *The Nation* stood with those other, not too numerous reformers who tried to confine the new explosive force within legal bounds. It fought particularly for an honest civil service and free trade as barriers to the flagrant use of privilege, and week by week exposed corrupt practices, in and out of government, with facts and plenty of moral courage.

But *The Nation* never challenged the "right" of business enterprise as such to apply freely all its energy to the opportunities offered by natural wealth and machine power. Godkin's devotion to the gospel of Manchester precluded any such challenge to the basic premise of the burgeoning American system. In fact, he used his best sardonic humor to demolish heretics like the New York *Tribune's* cantankerous correspondent Karl Marx, or William Demarest Lloyd, whom John Chamberlain called the "father of all the muckrakers," or Henry George and his Single Tax movement, or Edward Bellamy, whose fabulously popular "Looking Backward" anticipated the

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stern utopias which have since been put on paper. Regarding all attacks on the underpinnings of capitalism as basically uninformed and wrong-headed, *The Nation* firmly refused to recognize in the beginnings of popular resistance—the activities of Populists and Knights of Labor and the early Socialists, of Greenbackers and Grangers and Free Silverites—anything valid or promising. Rooted in the liberalism of Adam Smith, it relied on the application of moral standards to individual effort as the only remedy for economic sin and political unrest. And while some of the correctives *The Nation* prescribed, notably civil-service reform, made some headway during the reign of the Big-Business Republican oligarchy, corruption was not noticeably lessened or the rule of the Robber Barons curbed until popular unrest became a political threat. The force behind the new industrial revolution was too immense to be contained either by moral suasion or the weak and turbulent movements then coming into existence.

Tomorrow's World

So much for the last-century prototype of the greater postwar revolution that faces us today. The present editors of *The Nation,* planning this anniversary issue—Vol. 180, No. 25—should have a better notion of what lies ahead than their predecessors had ninety years ago. For one thing The Nation Associates pioneered in this field by holding two important conferences—in 1945 and 1950—dealing with the problems of nuclear power. Also, despite rigid government security controls, a good deal more is known about the new technology and new sources of power than was known in 1865 about the future uses of oil and steel, for example, or the transforming effect of electricity on production and transportation. The pages which follow give what seems to us a remarkable survey, in layman's language, of existing knowledge, plans, and facilities in the field of nuclear power, as well as the fabulous benefits the unlocked atom offers mankind—if total destruction is averted. At least, in 1955, we know enough to understand the choice that science has offered our society: either to end war or accept its own end, and very possibly that of the earth itself. This primary issue is stated by Bertrand Russell on pages 515-517 with his usual, almost frightening, clarity and logic. We know, too, some of the prospects for making desert lands flower and hunger-ridden peoples emerge into health and plenty. These are analyzed by other experts who reveal, along with the dramatic chances for human advancement, some of the physical dangers, as well as the enormous social and economic problems, that will accompany every new application of nuclear energy.

But granting this much prevision, the greater part of the territory ahead is still unsurveyed, and the surprises in store for the nuclear pioneers will be more numerous and alarming than those their forbears met in the Western wilderness. The rewards will no doubt be proportionately greater. Before me, as I set down these words, is an advertisement out of a recent New York *Times.* It begins with these words: "ENGINEERS! SCIENTISTS! Unlimited opportunities in Atomic Power at Westinghouse." Under them appears the potent symbol of the atom, and under that the following information: "At a new plant on the outskirts of Pittsburgh, Pennsylvania, atomic energy is being explored as a source of power for transportation and industry. Opportunities in this new field are unlimited for: . . ." And then follows a list of the sorts of highly specialized technicians required, with the final assurance that salaries are "open."

Although this is not the first such ad to appear in a newspaper of general circulation it must be among the earliest; and I think it is a significant landmark on the road we have taken. "Unlimited opportunities"—as in the days of the first electric power stations, the opening of the first big oil fields, the first vast land grants for railway enterprise. Can we even begin to picture the unfolding of the coming revolution in power or the political and social consequences it will explode? I was struck by a few lines in David O. Woodbury's imaginative projection on page 533. "America's development of the atomic weapon," he says, "broke every rule of scientific procedure. Thousands of men and women were commandeered

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into a research that many of them feared and mistrusted. They did this under extraordinary restraints of secrecy. . . . They telescoped into five short years a work that should have taken fifty or a hundred. But they won. . . ." And he suggests that had they not operated "in this headlong fashion, our present generation, the next, and perhaps the next after that would have gone without the benefits of this wondrous new power." No doubt true. But does not this very example raise questions for the future? Suppose the benefits are such that Big Business, backed by government, sees profit and national advantage of equal dimensions in applying similar methods to industry? What vistas of "military socialism" the Woodbury projection opens!

Or, as a more immediate challenge, we should ponder the possibilities Leland Olds describes on pages 551-553. No one can doubt that private business will, in this country, take over the major share in making and distributing nuclear power for industrial purposes. But no one doubts, either, that the government—which is to say the taxpayers—will absorb the losses and cover the risks in the early stages of atomic development; this is the historic tribute of free enterprise to socialism. The real question is whether even a reasonable check can be put on the race for profit and dominance once the heavy initial costs have been amortized. We can assume that a new army of Robber Barons is just over the atomic horizon—waiting. The safeguards Mr. Olds suggests are modest; yet if they are not established now, before things get out of hand, the result will be the Greatest Giveaway of all time.

The task of a liberal journal like *The Nation* is a double one: it must devote its energy and its limitless independence to the major task of helping to prevent war and so release the atom for a regenerating role in human society; and at the same time it must resist the capture of the new power by special interests—whether of business or of nationalism.

This is the important lesson we should have learned from the experience of the early *Nation* and its editors: the great forces of change can be harnessed and used for the enrichment of people's lives only if their revolutionary impact is understood and dealt with in its own terms.

I. INTRODUCTION

THE CHOICE IS OURS

Coexistence or No Existence . . *by Bertrand Russell*

THE recent changes in the technique of war have produced a situation which is wholly unprecedented. War has existed ever since there were organized states, that is to say for some six thousand years. This ancient institution is now about to end. There are two ways in which the end may come about: the first is the extinction of the human race; the second is an agreement not to fight. I do not know which of these will be chosen.

Neither the general public nor the majority of powerful statesmen have as yet realized that war with modern weapons cannot serve the purposes of any government in the world. It is of the first importance that this should be realized by those who control policy both in the East and in the West. It is generally conceded by those who are in a position to speak with authority that no complete defense against an H-bomb attack is possible. We must, I think, consider it the most likely hypothesis that if a great war broke out tomorrow each side would be successful in attack and unsuccessful in defense. This means that in the first days of such a war all the great centers of population on each side would be obliterated. Those who survived this first disaster would perish slowly or quickly as a result of the fall-out from radioactive cloud. Destruction of life from this cause would not be confined to the belligerent countries. The winds would gradually spread death throughout the world. This, at least, is what is to be feared. It cannot be said that the worst outcome is certain, but it is sufficiently probable to deter any sane man from incurring the risk.

Apart from the totality of destruction, there is another new element in the situation. In old days if you had a military advantage over your enemy, you might hope to win in time. But now, if each side has enough H-bombs to wipe out the other, there is no longer any advantage in having twice as many as your adversary.

Both in the United States and in Great Britain there has been much talk of civil defense. Russian military journals contain talk of the same kind. All such plans, I am convinced, show either ignorance or hypocrisy in those who advocate them. Deep shelters would enable a portion of the population to survive the first explosion, but sooner or later these people would have to emerge from their shelters into a radioactive world.

Although the H-bomb is the center of public attention at the moment, it is only one of the possibilities of destruction which science has put in the hands of irresponsible

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politicians. Chemical and bacteriological warfare are studied by all powerful states and may have consequences at least as horrifying as those of the H-bomb. There is no visible end to the methods of inflicting death that may be invented. Even if a portion of the human race were to survive a great war now, it cannot be doubted that the next war, if scientific technique survives, would complete what its predecessor had left unfinished.

There is therefore no escape from the choice that lies before us: Shall we renounce war, or shall we bring our species to an end?

Escape from Reality

If men realized that these are the only alternatives, no one can doubt that they would choose peace. But there are various ways in which people escape the realization of unpleasant facts. I have seen statements by Russians and Chinese that a thermonuclear war would of course destroy the rotten capitalistic civilization of the West but would not vitally injure the sturdy Communist nations of the East. I have also seen statements by American authorities claiming that the West would be victorious. Both seemed to me, if genuinely believed, to be mere fantasies of wish-fulfilment and, if not genuinely believed, to be part of the silly game of bluff which great nations have been allowing themselves. I hope that this is beginning to be understood. Recently there have been hopeful signs that neither side is willing to push issues to the point of war. And with every month that passes there is a better chance that statesmen both in the East and in the West will become aware of some of the important facts by which their policy ought to be guided.

Another widespread delusion is that perhaps in a great war H-bombs would not be employed. People point to the fact that gas was not employed in the Second World War. They forget that gas had not proved a decisive weapon even in the First World War and that in the meantime gas-masks had been provided which were a complete protection. Any analogy is therefore entirely misleading.

It is thought by many that the first step forward should be an international agreement not to use H-bombs in the event of war, and this is generally coupled with the suggestion that both sides should destroy their existing stock of these weapons. This suggestion has certain merits but also certain drawbacks. Its chief merit is that if the destruction of existing stocks were honestly carried out, the danger of a sudden attack in the style of Pearl Harbor would be lessened. Against this we must set the fact that no system of inspection can now make sure that bombs are not being manufactured. This is a new fact. At the time of the Baruch proposal it was still possible for an inspectorate to gain control of the raw materials, but this is so no longer. Each side would therefore suspect that the other side was manufacturing bombs surreptitiously, and this might make relations worse than if no agreement had been concluded. What is even more important is that, if war did break out, neither side would consider itself bound by the agreement, and after a certain number of months H-bomb warfare would be in full swing. Only by not making war can the danger be avoided. We must therefore turn our thoughts away from war to the methods by which peace can be made secure.

Peace by Stages

The transition from the cold war to a condition of secure peace cannot be made in a day. But it can be made, and it must be made. It will have to be made by stages. The first stage will consist in persuading all powerful governments of the world that their aims, whatever they may be, cannot be achieved by war. In this first stage, scientists—not only nuclear physicists but also physiologists, geneticists, and bacteriologists—have a very important part to play. Their discoveries have created the dangers, and it is their obvious duty to arouse the public and the governments to a sense of the risks they are running. They may, in performing this duty, be compelled to take action of which their governments disapprove, but loyalty to mankind should be for them the paramount consideration. I am convinced that it is within their power to persuade the governments both of the East and of the West to look to negotiation rather than war for a solution of their problems.

The next stage must be to create temporary machinery to negotiate settlements of all the questions at present causing conflict between East and West. It will be necessary to refer such questions to a body of negotiators in which East and West have equal representation and the balance of power is in the hands of the neutrals. I do not venture to suggest what solution should be be reached on any of the vexed questions of the present. I think that a body constituted as I have suggested would avoid gross unfairness to either side, and subject to this condition almost any settlement would be preferable to a continuation of the present state of tension. A very important part of any settlement should of course be a drastic reduction of armaments. It is hardly to be supposed that the very delicate negotiations which will be required can be conducted successfully in the atmosphere of strained hostility that has existed during recent years. Each side will have to abandon perpetual abuse of the other and learn to practice that degree of toleration which after centuries of warfare was at last achieved between Christians and Moslems and between Catholics and Protestants. We cannot now wait for the slow operation of reason through the discouragements of long indecisive wars. We must learn in advance a manner of thinking and feeling which in the past has been learned slowly and through bitter experience. I will not pretend that this is easy. But if men can be made to realize the dreadful alternative I do not think it will prove impossible.

The Third Step

If the immediate problems that now divide East and West were settled in some such way, we could reach the third stage of progress toward secure peace. The international problems of our day are not the last that will ever arise. There will be new problems, perhaps dividing the world quite differently from the way in which it is now divided between Communist and anti-Communist blocs. So long as there is not an established international authority capable of enforcing peace, the risk of war will remain, and with every advance in science the risk will become more

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terrible. The international anarchy resulting from a multitude of states with unrestricted sovereignty must be brought to an end. The international authority which is to end it will have to be federal and endowed with only such powers as are necessary for preserving the peace of the world. The most important of these powers, and also the most difficult to secure, will be an obvious preponderance of armed forces over those of any national state or alliance of states. The anarchic liberty at present enjoyed by sovereign states is dear to most people and will not be surrendered easily, but it will have to be surrendered if the human species is to survive. The process required is a continuation of that which occurred in the fifteenth and sixteenth centuries. Before that time powerful barons in their castles could defy national governments, and there was the same sort of anarchy within a nation as now exists between nations. Gunpowder and artillery put an end to internal anarchy in France, Spain, and England. The hydrogen bomb has the same part to play in ending international anarchy. The loss of liberty, though it may be distasteful, is precisely of the same kind as that which private individuals suffer by being forbidden to commit murder, for after all it is the right to murder which hitherto sovereign states will be asked to surrender.

Legitimate Hopes

I have been speaking of dangers and how to avoid them, but there is another thing which it is just as important to emphasize, for while fears are at present unavoidable, hopes are equally legitimate. If we take the measures needed to end our fears, we shall thereby create a world capable of such well-being as has never been known and scarcely even imagined. Throughout the long ages since civilization began, the bulk of mankind have lived lives of misery and toil and bondage. All the long burden of misery that has darkened the slow progress of mankind has now become unnecessary. If we can learn to tolerate each other and to live in amity, poverty can be abolished everywhere more completely than it is now abolished in the most fortunate nations. Fear can be so much diminished that a new buoyancy and a new joy will brighten the daily lives of all. The work of science, which while war survives is largely evil, will become wholly beneficent. Nothing stands in the way but the darkness of atavistic evil passions. New technical possibilities of well-being exist, but the wisdom to make use of them has hitherto been lacking. Shall we collectively continue to turn our back upon the things that each one of us individually desires? We can make a world of light, or we can banish life from our planet. One or other we must do, and do soon. A great duty rests upon those who realize these alternatives, for it is they who must persuade mankind to make the better choice.

THE ROLE OF ENERGY

Mainspring of Civilization . . *by Farrington Daniels*

WHAT makes the difference between a primitive society living at a survival level and a rich, highly industrialized nation? Many things. National resources, such as water, good agricultural land, and minerals, are important. So are large economic units without trade barriers, and political security and peace. Perhaps more important are education, science and technology, and human initiative and team work among people working on a common project. However, the obvious material requirement for a high standard of living is cheap abundant energy.

FARRINGTON DANIELS, chairman of the department of chemistry at the University of Wisconsin, is the author of many text books and has done extensive research in atomic energy.

In modern times engines run by coal, gas, or water power multiply enormously the energy available. Primitive man working with his arm muscles alone had to use all his energy to win a bare existence. As he lengthened his arm with tools and increased his strength with animals and carts he could accomplish more, and labor in the community could be diversified. But as late as the settlement of America men could wrest little more than a living from the land. The big advance started with the machine age. Abundant and cheap mechanical power made possible the increase in population and higher standards of living of the nineteenth century. Today the United States supports 160,000,000 people in comfort.

To see how an energy-rich civilization differs from an energy-poor civilization, we can try to imagine what life in a modern city would be like if the sources of fuel and electricity were suddenly cut off, or we can contrast industrialized and non-industrialized countries at the present time. We have had small-scale illustrations of how cities are affected by a stoppage of normal power supplies through hurricanes, strikes, or bombing. Heating, lighting, refrigeration, transportation, and food deliveries are halted. Movement of the population to the country would not solve the problem in the United States because our farms are also dependent on mechanical power, for tractors, transportation, and so on. To go back to the "horse-and-buggy days" becomes more unthinkable every year as we become more and more dependent on the power-driven machine.

All our energy comes originally from the sun. Through the mar-

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velous process of photosynthesis, which we are just beginning to understand, the carbon dioxide in air and water combine in living plants through the agency of sunlight in the presence of green chlorophyll. The product is then available for food. In rural, non-industrialized areas this product is the only source of the work done in the community. The process is continual, and the people live on the current output of the sun. Wind and water power are other sources of energy which will continue indefinitely. But industrialized communities cannot begin to live off the current product of sunshine. For running their machines they depend almost entirely on the solar energy of bygone ages, accumulated by photosynthesis and preserved for us by geological accidents as fossil fuels. Buried trees give us coal, and the decomposition of small photosynthesizing organisms give us petroleum. Unfortunately, the fossil fuels can be exhausted. They are irreplaceable because their rate of production is so so very slow.

How much fuel do we need, and how long will our reserves last? The world's food requirements are about 2,500 kilocalories per person per day; the fuel requirements of its machines are about ten times as much. In the United States we feed ourselves about 3,000 kilocalories of food per person per day, but we feed our machines at the rate of 150,000 kilocalories. This energy runs our factories, our automobiles, and our trains and heats our buildings; it does almost all our work for us except what is done by hydroelectricity. The world's demands for energy are increasing rapidly not only because the population is increasing but also because each person is demanding more of the product. The industrialization of underdeveloped countries will increase greatly the total fuel requirements, and it is well to remember that countries already industrialized contain only a small fraction of the total population of the world.

How long can we continue to expand this energy-based civilization before our fuel reserves begin to give out? The answer is not clear. Past worries over the exhaustion of petroleum have not been borne out. Each decade we use more gasoline than was predicted, but through scientific searching we find additional supplies. This cannot go on indefinitely, however. According to one conservative guess we have used up about 5 per cent of the world's supply of fossil fuel, and most of this consumption has been in the past few decades; only negligible amounts of fuel were consumed before the machine age. Natural gas will give out first, petroleum next; coal will last longest. As long as we have coal the chemist can provide liquid and gaseous fuel—at higher prices. But eventually, perhaps in a few hundred or a thousand years, at our present rate of consumption fossil fuels will be pretty well used up. Already some industrialized areas are beginning to feel the effect of dwindling coal reserves: as the best deposits are consumed, inferior or more expensive seams must be mined. The future of our fossil fuels is discussed authoritatively in several recent books—"Energy Sources: the Wealth of the World," by Ayres and Scarlott; "Energy in the Future," by Palmer Putnam. If one holds, with Putnam, that the situation will become critical when dwindling fuel supplies double in price, the problem is one for our own generation and that of our children.

How can we conserve our fuel supply and leave some of this rich heritage to our descendants? We have learned to use fuel more efficiently, replacing fireplaces with furnaces and steam locomotives with Diesel engines. We could ration ourselves; it is indeed extravagant to use a 150-horse-power automobile to move a 150-pound man along the road at 60 miles an hour. A more effective solution would be to find a substitute for coal, oil, and gas.

Atomic energy and solar energy are hopeful possibilities. The total amount of atomic energy that can be produced by nuclear fission of known supplies of uranium (and

Prophecy and Fulfilment

To The Nation Associates goes the distinction of having been the first institution to focus public attention on the peace-time potential of nuclear energy. In two forums, the first in December 1945, the second in April 1950, it projected a world of peace and abundance at a time when few scientists—let alone ordinary people—had the imagination to foresee an atomic revolution for the benefit, rather than the destruction of mankind.

The first forum, on The Challenge of the Atomic Bomb, took place on December 1-3, 1945, barely five months after the A-bomb was dropped on Hiroshima. The speakers included Harold C Urey, Nobel prize-winner; Herbert Evatt, former foreign minister of Australia; Henry deWolf Smyth, afterwards appointed a member of the Atomic Energy Commission, a post from which he resigned last year; Thomas K. Finletter, later Secretary of Air; Boris Pregel, president of the Canadium Radium and Uranium Corporation, and who collaborated on the Manhattan Project and is a member of various scientific societies; and many others of equal distinction.

In a world still shocked by Hiroshima, the forum's concentration on the possible peace-time future of the atom was itself impressive. Even more so was the clarity with which Boris Pregel predicted in his paper the shape of things to come. A few paragraphs from his prescient speech of 1945 follow:

"We think the first important application of atomic energy will be the production of cheap power by large plants, the location of which will not be dependent on natural resources. This is a tremendous advantage, especially for desert regions—for underdeveloped world areas—and for the development of countries with few natural resources. . . . Power is the basis of the cost of everything. Cheap power in unlimited quantity means an abundance of cheap products and, in connection with it, the reduction of working hours.

"Eventually we may convert any kind of matter into energy, not limiting ourselves to relatively rare materials like uranium. . . . We will be able to produce artificially all kinds of materials because we will have at our disposal the tremendous energies needed. . . ."

How accurate was the general trend of Mr. Pregel's predictions can be judged by the reports in this special issue of The Nation.

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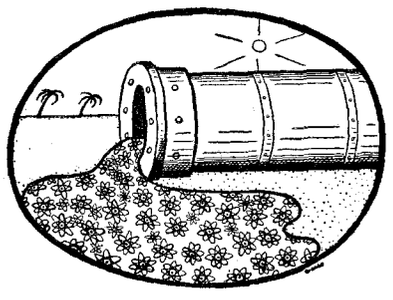
thorium) exceeds the total amount obtainable from all our fossil-fuel supplies. When the economic problem of extraction of uranium from very low-grade ore is solved, the atomic energy available can *greatly* exceed our potential fossil-fuel energy. But uranium and thorium are in limited supply just as coal and oil are. Nuclear fission of hydrogen remains a difficult and remote possibility for continuing our sources of energy into the distant future.

The sun will be with us, however, as long as there are people on the earth. We are just beginning to think about using solar energy. Several symposiums have been bringing experts together for discussion of the problem—at Wisconsin, sponsored by the National Science Foundation, in 1953, in India in 1954, and in Arizona in 1955. The Rockefeller Foundation has given a substantial grant for research into the utilization of solar energy, with particular emphasis on its application in non-industrialized areas.

Atomic energy and solar energy will supplement each other as new resources for doing some of the world's work. It is unlikely that either will render obsolete any of our power produced by the combustion of present-day fuels. They will merely help to meet the expanding demand for power. Atomic energy will be furnished by large expensive units, such as central power stations for generating electricity and engines for driving ships. Solar energy



is more likely to be turned to practical use in small isolated units in non-industrialized areas. Small, low-priced atomic-power units are not feasible on account of the requirement of a certain minimum mass before any heat is generated and on account of the need for elaborate controls and safeguards. But there is no low technological limit to the size of solar units.

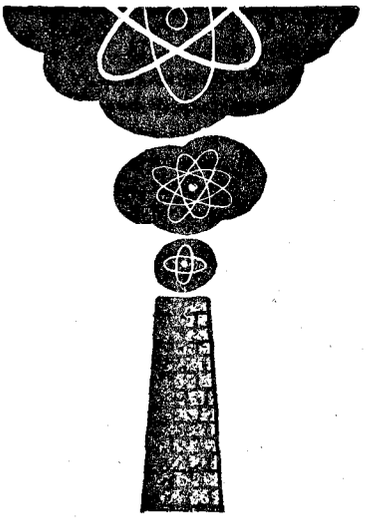
No new principle is involved in solar engines. The problems are economic. Sunlight is so low in intensity that the collecting apparatus has to cover a large area. Large areas of glass or metal are expensive. Thin plastics which can be produced for a few hundred dollars an acre offer possibilities which should be explored. Focusing mirrors are also expensive, particularly if they are turned by machinery to follow the movement of the sun. Another obstacle to the general use of solar energy is the difficulty of storing it for use at night.

Solar energy cannot compete now with coal or petroleum or water power, but possibly with further research it can compete with manpower and animal power in regions lacking all other sources of energy. In trying to develop solar energy for non-industrialized areas the emphasis should be placed not on efficiency but on low cost of investment and upkeep. The sun's rays falling on the roof of a house a thousand square feet in area provide nearly half a million kilocalories of heat a day. If used to operate a solar engine of 5 per cent efficiency, this could theoretically give about three kilowatts of power while the sun is shining. No practical, economical device is available as yet to convert the heat into power, but the incentive for research is present.

Solar Cooking

The long-range hope for utilizing solar energy lies not in engines which are subject to stringent thermodynamic limitations but in photochemistry and photoelectricity. The new solar battery announced by the Bell Telephone Laboratory is able now on a small scale to convert sunlight directly into electricity with 11 per cent efficiency. Further research is necessary to make such devices economical, and there is still the problem of storage.

Other applications of solar energy are easier—solar house-heating, solar refrigeration, solar cooking, and the solar distillation of sea water to give fresh water. All these operations are possible, but further research is necessary before they can be economical. They cannot compete now with electricity or gasoline, but perhaps they can find use in areas where



these cheap sources of energy are not available.

Some important by-products might follow the utilization of solar energy in underdeveloped areas. Solar heat for cooking in India could save the camel and cow dung now burned for fuel, and valuable fertilizer could be returned to the soil. But the cookers would have to be much cheaper than the $14 they now cost in India. Pumping of water for irrigation would be one of the first uses for solar engines when they are developed. For this the intermittent nature of the sunlight would not be a serious handicap. Hours devoted to gathering wood and grass for heating and cooking could be spent more profitably if a solar heating device could be used. Solar refrigeration would help conserve the food supply, and fresh water from solar distillations might open up new areas for habitation and thus help to relieve population pressures. Village industries are among the benefits that could come from new sources of energy. For healthy economic conditions something must be produced to sell outside the community in return for things brought in from the outside.

The industrialized countries are eager to help provide this energy for non-industrialized countries. If they solve the problem for these areas the techniques developed may lead to reductions in costs that will bring solar and atomic energy into competition with fuels in the industrialized areas before our great-grandchildren's energy problems become acute.

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II. WHERE IN THE WORLD?

Obviously atomic energy will ultimately be harnessed everywhere. But the rate and direction of initial development in each country depends on many varied factors. Dr. Bronowski's brilliant report on southern Africa provides a setting for the surveys, in this section, of other "sample" countries, each of which can be said to represent a type. Thus Great Britain has much in common with all the industrialized Western nations, as Israel has with its Arab neighbors in the under-developed Middle East region.

SOUTH AFRICA'S NEEDS

The Race for a New Fuel . . *by J. Bronowski*

London

All the countries of the world are now looking afresh at their resources of natural energy. In the past, when national balance sheets were redrawn in this way, the motive was fear; nations were alarmed at the rate at which they were using their irreplaceable stocks of energy. Today there is a new note in the scrutiny of these resources. Every country is asking how it will be affected by the coming of nuclear energy, which is now imminent. And every country hopes to find in this a store of riches which will dwarf the wealth that hitherto has grown from coal and from oil.

Consider briefly the energy resources of the world in fossil fuels and their rate of use. Take as a unit all the oil and natural gas that have been burned since petroleum was found in Pennsylvania a hundred years ago. The total of coal burned through the past is about four times as great, in energy content, as this total.

At first glance our reserves seem adequate to this rate of use. World reserves of oil and natural gas, proved and suspected, are about ten times as large as the amount of oil and gas already used. Coal reserves in reasonably good seams—say, those which can be mined at not more than twice current costs—are about fifteen times larger than the amount of coal already used. But this is too simple a calculation, because it ignores the growing rate of use. During the drive for production in World War II, the world consumption of coal reached 2,000,000,000 tons a year, which is nearly one ton per head of world population. Most of the coal and oil that has been burned in the whole history of the world has actually been used in our own lifetime. Half of all coal ever used has been used in the last twenty-five years; half of the oil used has been used in the last ten years. The nations have indeed had cause for alarm.

The discovery of nuclear fission in 1938 changed this balance sheet radically. Uranium and the other heavy elements have an altogether different history from the fossil fuels. They are, in fact, the only sources of energy on earth which have not been induced here by the sun and which therefore do not ultimately derive from fusion of hydrogen into helium nuclei in the sun. They date from the beginning of the earth and are present everywhere—in granite, in shales, in gold and silver mines.

How much nuclear fuel there is in the world depends on how much we can afford to pay for it. If we set as our limit the fairly high price of $100 a pound for metal, then there are at least 20,000,000 tons of uranium and a million tons of thorium to be recovered from low-grade ores. The theoretical energy content of this total is fifty times greater than that of all the world's coal and oil reserves. Even if the nuclear pile can extract only a part of this energy, the addition to the world's resources is spectacular.

There are, however, important differences between countries, which will be critical in determining the speed with which they can take advantage of the new dimension of energy which the nuclear fuels have opened. One outstanding difference, of course, is the actual occurrence of ores of uranium and thorium. Widespread as these are, the effort needed to mine and refine them covers a great range between, say, the rich deposits at Shinkolobwe in the Belgian Congo and the poor monazite sands of Southeast Asia. It may be that at any moment another great discovery about the structure of the nucleus may lead to a new way of tapping its energy, as the discovery of the neutron in 1932 led to the exploitation of nuclear fission. Or we may simply discover how to control the nuclear fusion of some light element and thereby reach in manageable form the source of energy which now makes the stars and the hydrogen bomb glow. Such a discovery may make uranium oxide once again a mineral of no importance except to color ceramics. But there is no sign of such discoveries, and we must assume that, certainly in this century, controlled nuclear energy will continue to depend on the fission in atomic piles of the very heavy elements. The presence of large deposits of uran-

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J. BRONOWSKI became interested in atomic energy at the close of World War II and was sent by the British military to report on the effect of atom bombs on Japan in 1945. He is now Director of the Central Research Establishment of the British National Coal Board. This article appears with the permission of Optima, *a South African journal.*

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ium is therefore an important advantage to any country.

A second difference between countries, equally important, is their state of industrialization. From the mining of crude uranium oxide, present perhaps only as one hundred parts in a million of the ore, to the final assembly of the aluminum-encased slugs in a graphite-moderated pile where all the metals must be free from impurities to one part in a million, there is a sequence of expensive and recondite industrial operations which no backward country can command. Indeed, no small country can afford to set aside for years all the industrial resources that are required to develop nuclear energy. On the other hand, the highly industrialized countries may hold back in another way. So much of their potential is already invested in more traditional forms of production that they may be reluctant to make nuclear energy their first concern. It may well be, then, that the outstanding role of nuclear energy in this century will be in those countries which are only partially industrialized, but in which industry is expanding rapidly and which offer a handsome field for investment.

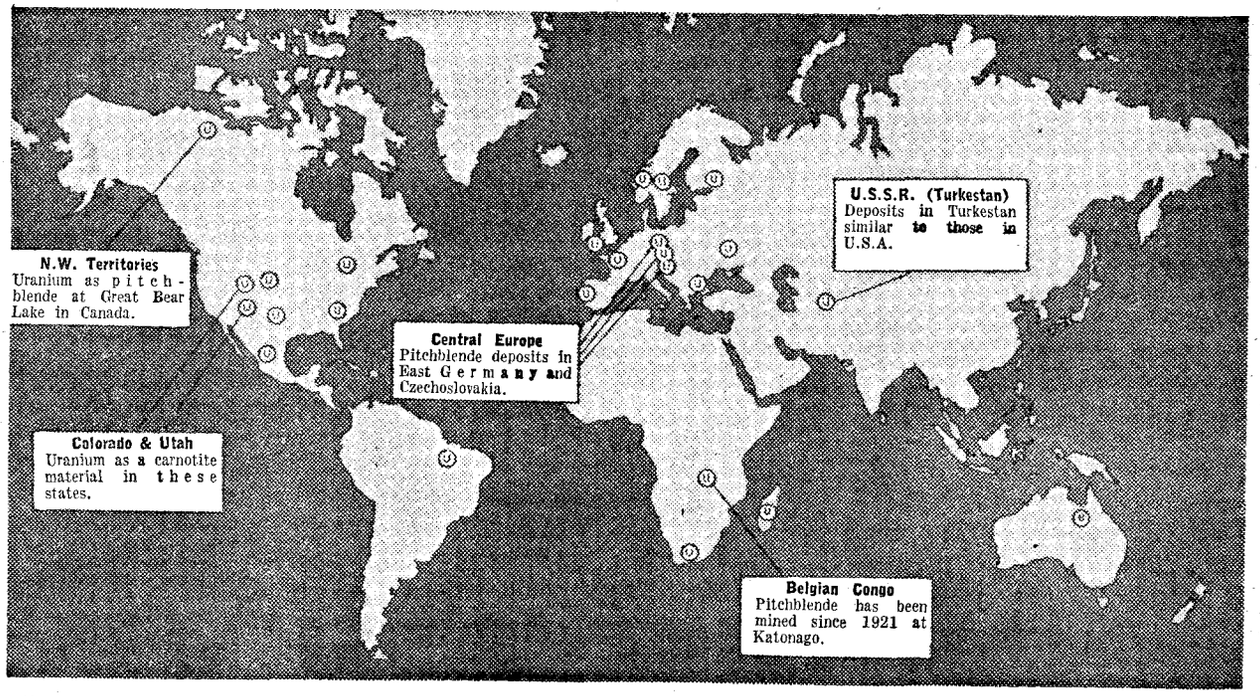
If we combine these and similar considerations, we can single out three or four areas in the world where nuclear energy can enter an expanding economy. One is in Australia, a second in Canada, a third in Brazil, and a fourth in southern Africa. A hundred years from now these may be the centers of the new industrial world.

Some measure of the industrial progress of southern Africa is given by its economic statistics. Just before the war, in 1939, the gross value of the industrial output of the Union of South Africa was about £175,000.000. During the 1950's the gross value each year has exceeded £700,000,000—an increase far greater than the mere inflation of money values. The same story is told by the high rate of capital investment in the Union and by the index of employment, which is now nearly twice as high for Europeans and nearly three times as high for non-Europeans as it was between the wars.

But the most striking, because the most fundamental, figure is again the use of energy, which means in this case the tonnage of coal mined. In 1934 the Union of South Africa mined 13,000,000 tons of coal. On the eve of the war, in 1938, it mined nearly 18,000,000 tons. Immediately after the war, in 1946, it mined nearly 26,000,000 tons, and this figure, a doubling in twelve years, was still rising year by year, and now exceeds 30,000,000. The amount of coal sold at the pithead in 1953 was well over 31,000,000 tons.

This rise speaks for the industrial progress of South Africa. And we see this in another way if we look at the pattern on which this coal is used. Of the 21,000,000 tons sold last year, power stations took, in round figures, 10,000,000, having doubled their consumption since 1938 and trebled it since 1931; the railways took 6,000,000, various industries (including gold mines) took 9,000,000, and households and the export trade 3,000,000 each. The main consumers, therefore, are the power stations, industry, and the railways. There is a marked contrast with the pattern of consumption in Great Britain, where the power stations run equal with households in using about 15 per cent of total production and the railways use less than half as much. The bias toward industry, and particularly toward electricity and transport, becomes more marked if we add to these figures for the Union of South Africa the remaining coal output in southern Africa, which is largely that of Wankie Colliery in Southern Rhodesia. The output of this colliery goes mainly to the copper mines, the power stations, the railways, and direct to industries. The output capacity of Wankie Colliery is at present some 3,750,000 tons, and it is expected to reach 5,000,000 tons at the beginning of 1956.

This has, indeed, been the history


N.W. Territories
Uranium as pitchblende at Great Bear Lake in Canada.
Colorado & Utah
Uranium as a carnotite material in these states.
Central Europe
Pitchblende deposits in East Germany and Czechoslovakia.
U.S.S.R. (Turkestan)
Deposits in Turkestan similar to those in U.S.A.
Belgian Congo
Pitchblende has been mined since 1921 at Katonago.

Uranium: World Sources of Supply

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of southern Africa coal and minerals since coal was first mined toward the end of the last century. The wealth produced in diamonds, and in gold, copper, and other metals, would remain locked in the soil if there had been no coal. There is no oil to take the place of coal, as it has done in all forms of transport and heating in the United States. On the contrary, the Union of South Africa is now sinking some £30,000,000 of capital into a plant at Sasolburg to make 55,000,000 gallons of petrol and 16,000,000 gallons of other oil products a year from 2,000,000 tons of coal. This will meet only about one-sixth of the Union's present use of motor fuel.

Lack of Water Power

Nor has southern Africa any large sources of water power to draw on, within reasonable distances of its industrial centers. In this respect it is exceptional in the world. The Copperbelt, in Northern Rhodesia, is so short of power that, in addition to the swift expansion of Wankie Colliery, it has made plans to import water-generated electricity from the Lualuba River, in the Belgian Congo, early in 1957. Even so, there will be a power shortage in Rhodesia by 1960; it is hoped by then to get some water power from a tributary of the Zambezi, the Kafue River, and later perhaps from the Zambezi itself at Kariba Gorge.

In short, water power can add only a little to the central resource of power in southern Africa, which is its coal. These coal reserves, proved at more than 200,000,000,000 tons, exceed those of Great Britain, and there is therefore room still for great expansion in coal mining. South Africa still mines only as much coal each year as Britain did in 1850, which is one-seventh of production in British mines today. There would, indeed, already have been a more rapid expansion in southern Africa but for the limitation set by railway transport and particularly by the shortage of rolling stock. As it is, the main expansion has naturally gone into the power stations, which since the war have expanded at the prodigious rate of 100 per cent and more each year.

How may the discovery of uranium in southern Africa change this pattern? For the time being, of course, uranium is being mined simply as another of the valuable metals in which southern Africa has turned out to be rich. Uranium oxide was first discovered in the eighteenth century associated with silver in the mines of Joachimsthal in Czechoslovakia—the silver which, coined into thalers or dollars by Maria Theresa of Austria, is still current coin in Africa and the Middle East. Almost as accidentally, uranium oxide was discovered to be strongly associated with gold on the Rand in 1944. (Its presence had, in fact, been reported in 1923, but the significance of the concentration in the slimes was not then appreciated.) The geological reasons for these associations are still obscure, the more so as the nations possessing these remarkable uranium deposits are secretive about all quantitative information. Uranium is dispersed throughout the earth's crust, with an average concentration that lies somewhere between one part in a million and ten parts in a million. But in the formation of the rocks the uranium has moved preferentially to some strata. For example, many granites contain twenty-five parts of uranium and more in a million, and some contain as much as one hundred parts in a million. That is, there are granites that contain more energy in a ton of rock than is contained in a ton of coal. Here the enrichment may be the result of ionic migration (the movement of electrically charged particles) during the formation of these rocks.

A different process is probably responsible for the laying down of uranium in association with gold in such rocks as those of South Africa. The proportion of uranium present here is undisclosed, but is small. The Union of South Africa has designated as "prescribed material," in effect, that which contains more than fifty parts of uranium in a million. This is equivalent to one-and-one-half ounces of uranium per ton, and is six or seven times the average gold content of these ores. It is therefore clear that the uranium being extracted in the South African goldfields is measured, at any rate, in ounces per ton.

At this concentration it is unlikely that the mining of uranium alone would be economic at present world prices. Where rocks are being mined for uranium alone, for example in Canada, the minimum grade seems to be rather over two pounds per ton—that is, one thousand parts in a million. But the South African deposits enjoy the spectacular advantage of being associated with gold. The mining of the slimes and wastes that now lie on the surface has already been paid for by the extraction of their gold; and current mining operations are bringing up gold and uranium for processing at the same time. The prospects are therefore exceptional even when the separate concentrations of uranium and of gold are low. Surface wastes of ore are now being worked at six mines or more, and the contracts already concluded extend to at least twenty-three mines. Even before these numbers were reached, it was estimated that the annual output of uranium would eventually reach a gross value of £30,000,000. This compares with a yearly value of gold production now of £150,000,000. In addition, a deposit of monazite is being mined in the Cape Province for its thorium and other rare metals, and other deposits may be found and mined in the future.

Some authorities have guessed that the total value of the uranium will ultimately exceed that of the gold. This is perhaps an extravagant speculation. But at the most modest estimate we know that the uranium deposits, since they have been contracted for to the British and American governments for ten years, will earn at least £300,000,000; and it is not difficult from this minimum figure to conjecture a more likely total of £1,000,000,000. The evidence is that this is the largest accessible uranium deposit in the world.

Shift from the Military

Until recently the preoccupation of the large powers with uranium and their anxiety to monopolize newly-found deposits were predominantly military. But in the last year the climate has changed, even within the governments of the nations that are already leaders of world industry. It is now plain that nuclear power, in spite of earlier pessimism, is indeed close. A generating station powered by a simple nuclear pile

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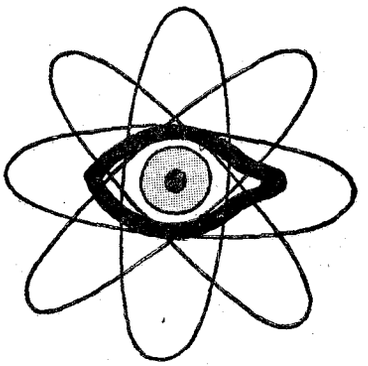
will be working in Great Britain in 1956. A second station is being built in Scotland, in which the nuclear pile will be several times more efficient, because it will breed fresh nuclear fuel for itself even while it generates energy. These two stations will generate at least fifty megawatts, and would therefore cater for the needs, in Great Britain, of an industrial town of fifty thousand inhabitants. Britain is perhaps ahead of America in these industrial plans, but the United States will not remain behind, and several large firms there are entering the field vigorously and on a broad front. Meanwhile, Russia has announced that it is using nuclear energy in industry. The details given, however, suggest only a small generator, comparable with the modest use of the waste heat from piles in adjoining buildings which is now familiar in Great Britain and America.

What are the economics of the production of electricity from a nuclear pile? There are two separate questions here, according to whether the pile makes mainly energy, or breeds, in addition, more fissionable material than it uses. The fraction of uranium that is fissionable of itself is present in natural uranium only as one part in 140; that is, when we have extracted a ton of natural uranium it contains only sixteen pounds of the fissionable variant or isotope of uranium. These sixteen pounds have an energy content of about 175,000,000 kilowatts, which is about one week's electricity output in the Union of South Africa. If the whole of the energy in the fissionable fraction of uranium could be tapped, and converted into electricity without loss, the yearly requirements of the Union would be met, in theory, by fifty tons of natural uranium.

Comparable Costs

This is, of course, an idealized figure. The fissionable material gives out its energy as heat, and this must be taken through the steam cycle to make electricity, exactly like the heat from coal. Even in the best modern power station, the efficiency of conversion from heat to electricity does not exceed 33 per cent, and more often it lies nearer 25 per cent. The fuel requirements are, therefore, increased three- or fourfold at once. And, in addition, the fissionable material itself may not be used to the full; if we are to make a circumspect appraisal, then we should take the most pessimistic view, which is that the pile might consume only five pounds of the sixteen pounds available in a ton of natural uranium. Overall, then, we should multiply the uranium requirement roughly by ten for caution. This means that the present electricity consumption in the Union of South Africa could be met by 500 tons of natural uranium a year. The



cost of this quantity of uranium, fully processed in the form required for a nuclear pile, can be estimated at about £5,000,000. This is of the same order as the cost of the ten million tons of coal that, at present, are used to generate electricity in the Union of South Africa.

This simple calculation shows that the costs of generating electricity from an ordinary nuclear pile or from coal are at any rate comparable. It would be idle to try to make the calculation much more exact now, when nuclear power is at a stage of development as infantile as were the steam turbine and the motor car in 1900. All that is worth doing is to see how these essentially similar elements of cost are likely to move, if development in the future follows foreseeable lines.

On one side, there is now, and will continue to be, a capital factor in favor of coal. The power station which contains a pile is necessarily a more elaborate structure than the coal-fired station. It must contain massive protection and elaborate safety and handling devices. The capital charges incurred will probably remain at a level twice as high as in the conventional coal-fired station. Indeed, if the efficiency of the use of uranium is increased by using faster and self-breeding nuclear processes, the capital cost will rise and not fall.

Against this there are two factors of cost in favor of the nuclear-power station. First, it is likely that the price of coal will continue to rise, and the price of uranium processing will fall. And, secondly, the uranium furnace, unlike the coal-fired grate, produces a by-product of value which we ought to set against our costs. As the five pounds of fissionable uranium disintegrates, it releases enough neutrons into the mass of natural uranium to convert something between three pounds and four pounds of that into plutonium. When the uranium rods have finished their useful life, therefore, they can be processed to extract this new fissionable plutonium.

Self-Breeder

These considerations lead us naturally to the principle of the self-breeding pile, which was proved practicable last year. Every pile, I have said, as it splits its fissionable nuclei, also makes some fresh ones. And it is possible to arrange the material in such a way that the nuclei that split make not less but more than their own weight of fresh fissionable nuclei. To do this, we must minimize the loss of neutrons within the pile. We therefore dispense with any moderator, which slows down the neutrons and makes them more liable to casual capture. Instead, we have a central core rich in fissionable uranium or plutonium, and we surround this directly with a thick blanket of natural uranium or of thorium. The neutrons released by fissions in the core are now captured in the blanket, and there make a maximum of fresh fissionable nuclei, either of plutonium or—if the blanket is thorium—of a fissionable variant or isotope of uranium. Such a pile, then, in addition to producing energy, actually breeds more fissionable material—from natural uranium or from thorium—than it uses. The blanket is removed and processed after a time, and the fissionable material is extracted.

In this way, therefore, in the breeder pile, we can, over a number of cycles, use cumulatively more than the five pounds of fissionable uranium in a ton that I have al-

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lowed, and, indeed, more than the fissionable content of sixteen pounds. How much more is not yet known. But it is usually assumed that, in the end, two hundred pounds of uranium in every ton will be used up, and some authorities go as high as seven hundred pounds. At either figure, the cost of the nuclear fuel would become negligible, and energy could become as cheap as water is in Europe and America. The present electricity needs of the Union of South Africa would be met by ten tons or less of natural uranium a year.

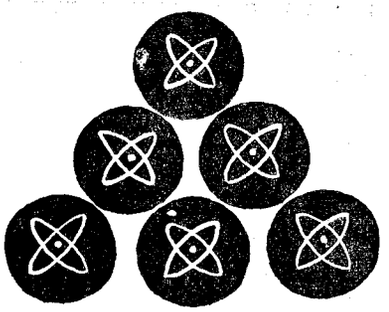
The Role of Nuclear Power

I have presented the figures in this way, using as my unit the present output of electricity in the Union of South Africa, in order that the reader shall have a yardstick which is both graphic and practical. Such figures are sometimes used to suggest that, very soon, we shall be ripping out the grates under the boilers of power stations, and putting in nuclear piles instead. Nothing of the kind is likely to happen, either sooner or later. Nuclear piles will become important in expanding economies like those of southern Africa. But their importance is not that they will take the place of coal, but will complement it and make its use selective. This is a fundamental point which we must look at in detail.

We can go to the crux of the matter at once and say that there simply does not exist in the world the industrial capacity in high-accuracy chemical and metallurgical processes required to undertake the conversion of already existing power stations. We may make grand computations of uranium requirements. But to clothe these in the aluminum containers, the sodium and potassium heat exchangers, and the cadmium control rods that make a pile work, to enrich uranium and extract plutonium, and to dilute the less deadly and safely store the more deadly radioactive wastes—all this calls for a new industrial revolution which has barely begun. When James Watt, about 1760, wanted to build his more powerful steam engine, he had to demand a new standard of accuracy: the tolerance between the piston and the barrel must not exceed the thickness of a sixpence. He searched Britain for workmanship as good as this, and had to settle in Birmingham to find it. Within a few decades his first demand created a new engineering industry of high precision.

Today nuclear engineering is making demands in metallurgy and chemistry which are equally unheard of. In order to keep a high and steady flow of neutrons in the pile, it is necessary to cut down impurities such as boron, which happens to capture them, to less than one part in a million. Indeed, the German failure to develop an atomic bomb may be traced directly to their unwitting failure to achieve this purity in graphite, and to their consequent miscalculation of possible neutron chain reactions. Moreover, it becomes necessary to find chemical methods to separate elements as similar as uranium and plutonium, and physical methods to separate their isotopes. This is the heart of the new industrial revolution: to extend to the industrial scale the most refined methods of chemical and metallurgical purification, measured in parts in a million, which hitherto have been the painstaking monopoly of the best research laboratories. Great Britain began its plans for nuclear power with a laboratory stock of plutonium which weighed less than a thousandth of an ounce. It took six years to multiply the scale of the process to pounds. It will be as long again before we can plan the building of nuclear-power stations on a scale to keep pace with the yearly growth of demand for electricity. The task is many times more severe for countries whose industries are less highly developed.

The task of nuclear power, in fact, is not to displace existing sources, but to try to meet the growing demand with which coal and oil cannot keep pace. The British example, at which I have glanced, shows the pattern. Great Britain now uses 35,000,000 tons of coal a year in its power stations. If it is to maintain its relative position in the world order of productivity, below the United States of America but above the rest of the world, it must expect to double this by 1975. Improved coal output can find some of the necessary addition. Some may be found by oil. But there remains a



foreseeable gap which will reach 20,000,000 tons of coal a year; and this gap only nuclear energy can close. This is why Great Britain has laid stress on the industrial exploitation of the nucleus from the outset, and why the British Electricity Authority has been first in the field in creating a special department for the design of nuclear-power stations. It hopes to build in the 1960's, over three to five years, 5,000 megawatts of nuclear stations, which, running day and night, will make up the shortage of 20,000,000 tons of coal a year.

In southern Africa, the need for electric current is equally urgent. Manufacture is expanding to balance the mining and extracting industries, and all make a high demand for power. The demand has been met since 1945 by increased coal output going to new coal-fired stations. This expansion will go on. But, as in Great Britain, there will still be a shortage of power, and a constant search for any means to expand the total of available energy. For the next ten years, southern Africa is likely to be restricted to water power as the only additional source. But even if electricity output can be doubled in that time, it will not suffice, and a gap of some millions of tons of coal a year will wait to be closed, before 1970, by nuclear power.

The ten-year contracts for uranium ore with the British and American governments presumably imply that the Union of South Africa will not itself make nuclear power for that time. This delay is not necessarily a handicap. The resource needed for the scientific and technical development of the design of nuclear piles are, I have said, at present beyond the means of any but the major powers. For example, the United States of America has built, for different experimental re-

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searches, more than twenty small piles, and is exploring the commercial development of six different types. Another exploration of different alternatives is going on in Great Britain and, it can be inferred from known achievements there, in Russia. By contrast, the lesser effort that France has been able to devote to this work has resulted in development work on only one type of pile; this, however, is interesting because, in order to minimize industrial processing, it uses uranium oxide in place of the pure metal.

Southern Africa will, therefore, be in a position by 1965 to choose those pile designs that are best suited to its power needs and to its own resources of uranium. It will, presumably, begin to make plans for these well before then. It has the scientific knowledge to do so; for example, a South African, Brigadier Dr. B. F. J. Schonland, has recently been appointed to the senior position in the direction of Britain's Atomic Energy Establishment at Harwell. And within the ten years, South Africa can certainly develop the techniques and the industries that are required to build and operate its first piles. Its achievement in the last five years in building fourteen plants to extract uranium, seven plants to make sulphuric acid for these, and a manganese dioxide industry for the process, is evidence enough.

Power Where It's Needed

What special function should its future piles take over? I have said that they will not replace the grates of existing power stations; instead, they will add to present generating capacity, and try to keep pace with an expansion which by 1965 may be straining to double the output of electricity.

We can be even more specific in prophecy. No one in his senses wants to build a nuclear-power station at a pit-head or at the dam of a hydro-electric scheme. The place to put a pile is where electric current is needed and coal and water power are remote. We can contemplate something more than merely inserting a few nuclear stations into the power system of southern Africa. In a country where mining and processing make major demands for current in places hundreds of miles remote from either coal or water power, the nuclear pile will offer concentrated power precisely where it is wanted.

This is, without doubt, the most important application of nuclear energy in large and thinly populated regions, like southern Africa, which are rich in minerals. At present, for example, the Copperbelt brings its coal more than six hundred miles from Wankie Colliery, and this in a country where railways are tenuous and wagons are short. The Copperbelt proposes to bring water-generated electric current from the Lualaba River in the Belgian Congo, several hundred miles away. To carry current over this distance has already meant stepping up the voltage to 220,000 volts, and, even at this tension, power losses become excessive, and costs onerous, at distances of over three hundred or four hundred miles.

The present consumption of current in the Rhodesias is something under 2,000,000,000 kilowatts a year. The development of mining will expand it to 4,000,000,000 kilowatts a year long before 1965. Coal and water power, including the new power station on the Kafue River, can just meet this demand. But suppose that the following ten years, from 1965 to 1975, enlarge the demand by another 4,000,000,000 units a year. Here is the ideal place for taking up the expansion with nuclear power. On the computations which I sketched earlier, 4,000,000,000 kilowatts is likely to require, in a breeder pile, four tons or less of natural uranium a year. Even the crude ore to produce this uranium would amount only to some thousands of tons. Thus the transport of neither the ore nor the processed fuel raises any problems. The existing transport difficulties, both for coal and for current, are cancelled at one stroke. There are transport and industrial problems in the construction of a pile, of course, and there will be later problems in the elimination of radioactive wastes; but they are certainly smaller and more manageable.

It is the concentration of nuclear fuels that makes them so attractive for dispersed and remote mining operations. The nuclear fuels will, as it were, abolish the distances which have handicapped South African mining. In a sense, this is the essence of the nuclear fuel: precisely that it is packed on a different scale of distances. Coal and oil, the fossil fuels, and other chemical fuels release their energy by the breaking of chemical bonds—bonds, that is, whose length is measured in distance between atoms. Uranium releases its energy at the breaking of a bond within the nucleus—a bond whose length is some million times smaller. Since energy varies inversely with distance, the bond within the nucleus holds some million times more energy than the chemical bond between atoms. This is the scale of energy comparison between nuclear and chemical fuels, some millions to one; and this, as a result of the invisible distances within these structures, serves to abolish the distances of transport.

Changing Mining Techniques

From this may grow an important corollary: an application of nuclear energy more specific than in general mining. It will, of course, continue to be useful to extract and smelt some ores with coal, which can act as a fuel and a reducing agent at once. But there are minerals whose extraction will take new lines, if power is cheap and plentiful on the spot. Electrolytic and electro-thermal processes which are experimental now will then become practical. Consider, for example, the metals to which the Paley Report to the President of the United States assigns growing importance and scarcity. Copper, zinc, cadmium, lead, magnesium; with them, tin, nickel, manganese, chromium and even iron; a new metal such as titanium, and the new semi-conductor, silicon—all these are likely to be derived by electric processes as soon as current can be had freely on the spot. The importance of such changes in process in the Copperbelt, where many of these metals are mined, is very plain.

But it is worth exercising our foresight in this more deeply. The use of electric processes makes, in general, for a high purity in the metal obtained. And I have already underlined the importance of high purity and of precise chemistry in the new industries on which the effective running of nuclear devices depends. To take a simple example,

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aluminum of the purity required to encase the uranium slugs would be unobtainable in any other way. What is now done for aluminum may become common practice in the mining districts, then, for other metals. My own view is that this promises to be the most important application of locally generated current from nuclear fission in the world's mining areas.

There are, of course, more speculative possibilities that are opened up by the presence of nuclear piles in mining districts. For example, the Copperbelt now mines about two million pounds of cobalt a year. Natural cobalt, irradiated in a nuclear pile, becomes radioactive in a way that is particularly suitable for medical use. This radioactive variant or isotope of cobalt is now taking the place of radium for the treatment of cancer. The pile recently built in Canada has therefore been designed specially to make possible the irradiation of a maximum of natural cobalt. In the future, radioactive cobalt can well become a major product of the Copperbelt, made on the spot in the very piles that provide power.

Again, it has been suggested that some neutron irradiation may become a means of separating valuable ores, or of grading industrial diamonds. But speculations of this kind, which are by no means unpractical, are endless. They all point to the same central consideration; the important consequences that can flow from the presence of nuclear piles at the mining area itself.

Let me summarize these detailed considerations briefly. Coal and uranium are both sources of power, and in southern Africa they are likely to be the major sources of power. In the expanding economy of southern Africa, power is short and is likely to become shorter; any addition to power resources is a gain. At present, uranium is simply being exported as a metal. In ten years from now, it can become an addition to the power resources.

Neither in this nor in other respects is uranium a rival to coal. It can complement coal, and take up the expansion of power needs that is outstripping coal production—for example, in Rhodesia as in Great Britain. And the advantage of uranium is that it can be used to generate power precisely where both coal and water are handicapped by the great distances—for example, in the Copperbelt. The nuclear pile as the central unit in an electricity-generating station has its ideal place in such mining areas. Even there, it will not wholly replace coal, which is a chemical as well as a fuel. And elsewhere in southern Africa the chemical wealth of coal will, of course, be increasingly exploited in its conversion into oil.

The nuclear pile in a mining area has, I think, an outstanding function. It can generate current on a massive scale, and so make possible something of a metallurgical revolution. For cheap current at the mine-head makes possible the production of materials of very high purity; and these materials will be the backbone of the new industries associated with the utilization of the nucleus.

This is foreseeable as a second industrial revolution: the application of the chemical standards of the laboratory to industrial processes. And southern Africa may well be in a position to take the lead in this, having resources of uranium close to its rich mining areas.

A 100-Year Program

I propose that there be initiated now a 100-year program for the financing, construction, and implantation of atomic reactors in the power-short, food-short, water-short areas of the world. . . . How could such a 100-year program be financed? So bold, broad, and unorthodox a program could not, of course, short of cartelization, be supported wholly by private capital. It is not merely a matter of money. Atomic energy cannot be equated or compared with any other previous manifestation of the physical world. We could no more see atomic energy monopolistically controlled than we could believe in the propriety—to say nothing of the possibility—of a monopoly controlling the moon or staking a claim to the sun. What we have at hand is a power so vastly benevolent—or so blackly malevolent—that decisions as to its use are the decisions not of persons but of peoples—or nations. . . . It is right, therefore, that such a program of sound economic investment should seek the participation of government funds. Let me point to some of the world markets available through the symbiotic—that is the mutually beneficial—Atomic Marshall Plan which I propose.

From July 1, 1951, to May 1, 1954, we sent to India and Pakistan a total of $78,828,000 in economic aid. Allocated and obligated but unspent funds total $91,188,000. I believe that these sums should . . . have been spent. Even in terms of American dollars and American construction costs at American wage and salary rates $170,000,000 today would buy for India between seventy-five and eighty portable atomic-power reactors, or three large stationary atomic reactors complete with reprocessing plants producing 300,000 kilowatts of electric power and incalcuable quantities of radioisotopes for industrial, agricultural, medical, and biological research. If, under the convention of counterpart funds, India and Pakistan should contribute equal amounts there might be built six large stationary atomic-power plants of 600,000 k. w. capacity or between 150 and 160 portable reactors.

The potentials for an already industrialized but power-short nation such as Japan are far more startling. Between 1945 and 1952 we gave Japan $2,276,000,000 in non-military economic aid and credits. If it had been possible to allocate an equivalent sum for the installation by American industry, but at Japanese assembly and construction cost, of industrial atomic reactors of the large stationary type, it is within the area of probability that Japan might have now in the neighborhood of a hundred stationary atomic-power plants with an installed kilowatt capacity of about ten million. Japan's total installed kilowatt capacity in 1952 was only twelve million.

Without considering the vast new industry which the manufacture of reactors and their power-plant components would create in the United States, the technological, scientific, and social benefits which would flow from an international atomic-aid program of this magnitude would be incalculable.

From an address by John Jay Hopkins, Chairman and President, General Dynamics Corporation, 59th Annual Conference of American Industry, December 1, 1954.

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THE BRITISH PROGRAM

1965 the Target Year . . *by Sir John Cockcroft*

London

FOR some years the Department of Atomic Energy has been developing the production and exploitation of of atomic energy in order to create a new source of energy to supplement coal, oil, and gasoline. This is being done because it is likely that our energy needs will greatly increase during the next twenty years.

In the course of the last three years the British atomic program has achieved its first objective. We have built two largish research establishments at Harwell and Aldermaston, one dealing with the civil and the other with the military side of research and development of atomic energy—though there is naturally some cross-tie and the work on the production of fissile materials which is carried out at Harwell contributes to the military side of the United Kingdom effort. We have established at Harwell and Amersham a major source of the world's supply of radioactive isotopes, and we expect this year to see products to the value of more than £300,000 ($840,000).

Our atomic-energy factories have recently been described in an official publication, and I will do no more than to say that our production of plutonium is established and that our diffusion plant at Capenhurst has started to produce uranium enriched in the light isotope U-235.

The Power Program

We are now embarking on the second main phase of our civil program, the development of nuclear power. It was decided to build first two nuclear-power units which are essentially a development of our earlier graphite piles. The pile is used as a source of heat. The graphite-uranium reacting core is inclosed in a pressure vessel—a boiler drum, if you like—and the heat from the uranium metal is transferred to four steam generators situated symmetrically round the reactor. The steam then drives a conventional turbo-alternator set, and substantial amounts of electricity will be produced. Quantities of the order of 50,000 kilowatts have been mentioned in Parliament. The efficiency of conversion of heat into electricity in these units will be limited by our present inexperience in operating the uranium fuels and their containing sheaths at high temperature. If we are limited to 400°C. the efficiency of conversion will be about 25 per cent. This is about the average of all the British Electricity Authority power stations, but a modern station which operates at higher steam temperatures and pressures has an efficiency of about 33 per cent. Nevertheless, we think an efficiency of 25 per cent is not a bad start. If later an improved metal sheath for the uranium fuel can be developed and the temperature and working pressure increased, higher efficiencies should be achieved and a substantial reduction obtained in the capital cost per unit of power generated.

The working of these first reactors is made more economic by the fact that they will produce plutonium as a by-product. This has a substantial value not only for military purposes but in the long run for use as an initial fuel for advanced types of power units such as breeders. When worked in this dual-purpose role, the operating conditions are easier and the cost of power is economic because of by-product value.

The design study of an alternative type of nuclear-power unit, which uses ordinary water instead of graphite as the core material surrounding the uranium rods, is now in being. The reactor consists of a pressure shell containing the uranium rods with water flowing past them to transfer the heat. The operating pressure may be in the region of 1000 to 2000 pounds per inch and this pressure will limit the temperature of steam which can be generated. Once again, thermodynamic efficiencies are likely to be about 25 per cent but may be increased by external super-heating. Such reactors can probably be built in much larger units, and the capital cost per unit of output will be lower than with the first type. The penalty for the additional simplicity and cheapness of construction is paid by having to use slightly enriched uranium as fuel—uranium in which the proportion of the light isotope has been increased in a diffusion plant. The Americans have announced that they are building a unit of this general type which, they claim, will develop power of fifty megawatts and possibly much more. Their first submarine nuclear-power unit has been built on this principle.

Comparing the Costs

It seems likely that one or both of these types of nuclear-power station will be used to supplement power from coal stations. Still later models of nuclear-power stations will probably operate at higher temperatures, perhaps using liquid-metal heat transfer, and will, we hope, equal the thermodynamic efficiencies of the coal-fired station.

How does the cost of nuclear power compare with that from coal? The main difficulty in answering this question is the present large factor of uncertainty in the utilization of uranium fuel. These thermal power units burn the light uranium and by their alchemical properties produce, at an almost equal rate, a new fuel—plutonium—from the heavy uranium. This in turn is burned and replaced by more plutonium. Small differences in the conversion factor make a great difference in the overall utilization of uranium, so

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that until more experience has been gained we are uncertain by a factor between three and ten of the amount of uranium required to produce a given amount of power. Early estimates of costs have been based on the lower utilization figures.

Another source of uncertainty is the capital cost of the nuclear-power stations. It is too early in the development phase to be precise about this: the cost of the first unit is naturally high. The best estimates at present are that the second model of the current design might have twice the capital cost of a conventional coal-fired station, while the water-moderated type of unit built for large power output should be considerably cheaper. The overall result is that the capital costs will be somewhat higher than for conventional power stations and fuel costs somewhat lower. It should therefore be possible to produce power at a price between the present B. E. A. average generating cost of 0.7d. per unit and 1d. per unit.

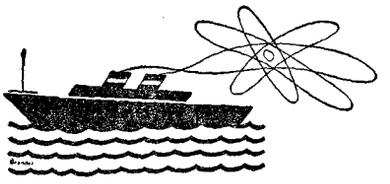
The time required for large-scale nuclear-power development depends a good deal on how urgent the need is. We will have to gain operating experience of our first graphite-moderated power unit and would then like to build an improved model of higher efficiency and lower capital cost. We would also like to build and operate the second type of power unit—the water-moderated reactor. This development period may easily cover eight years. After that, if results are satisfactory, it should be possible to devote some or all of our annual investment in new power stations to the nuclear types. Still farther along in the time scale are the breeder-reactor power stations, the object of which is to increase by a considerable amount the efficacy of utilization of uranium.

Location of Plants

The report of the Ridley Committee and B. E. A. reports have suggested that this country will be deficient in coal by about twenty million tons a year by 1965—though coal production could probably be increased by then—and power requirements seem likely to continue to expand. In order to do the work of twenty million tons of coal, nuclear-power stations developing 5,000 megawatts would have to be built. This amounts to about three years of constructional work at B. E. A. present levels and could be achieved by 1970, perhaps even by 1965.

The question naturally arises about the minimum and maximum practical sizes of power stations. They can be built for as small power outputs as we choose, though not with economy. At the other end of the scale, an output of 200 megawatts should be possible from a single unit.

In regard to the considerations that govern the choice of sites for nuclear-power stations, it may be said that the main consideration at the present stage of development is



that of safety. A major accident to a nuclear-power station might release radioactive products into the atmosphere. There would then be a danger zone down-wind for a limited distance and short time. Reactors of the thermal type are inherently very safe, and means of making them even safer are continually being devised. Nevertheless, we would probably want to site such stations twenty miles or so from a largish city. They need, however, be no more remote than many existing B. E. A. stations, such as those at Coleshill or Little Barford. The cost of extra-high-tension transmission over a distance of even fifty miles would add only 8 per cent to the capital cost of the power unit.

Apart from nuclear energy as a source of power, there are possibilities of important applications of radiation to the chemical-engineering industries. The polymerization of ethylene to polyethylene is carried out in industry at high pressures and temperatures. The presence of radiation from radioactive materials or from other sources can under some circumstances double the output of polyethylene. Alternatively, high temperatures can be dispensed with in the presence of radiation. This is being actively studied at Harwell and in the United States.

Radiation can also change the properties of plastics such as polyethylene. In particular it can greatly increase the resistance of polyethylene to high temperatures. This could be important, for example, in valve holders for use at high temperatures. Recently we were asked by a sister establishment to irradiate 20,000 valve holders. Polyethylene bottles, after irradiation, will withstand temperatures required for steam sterilization. Irradiated polyethylene might also be used for high-temperature insulation of cables.

Sources of Radiation

Three possible sources of radiation exist: (1) the plastics may be placed in holes in the shields of the piles; (2) the radiation from waste fission products may be used; (3) the high-intensity linear accelerators, which have also been developed at Harwell, may be employed. We are not yet sure which will be the most economical. Arrangements are being made for fuel elements discharged from reactors which are highly radioactive to be used as sources of radiation for such purposes.

We are therefore at the beginning of possible important applications to chemical engineering. You might ask what part industry plays in all these developments. We have during the last five years done a great deal to interest industry in the new developments. An annual power conference is held at Harwell to which fifty to a hundred guests from industry and universities and other government establishments have been invited. We have at these conferences had free and frank discussions on the status of the power-development program so that industry could judge when the time was ripe to participate. Two years ago one industrial group elected to join Harwell in a design study of the first power unit now being built at Windscale. After the design study was completed, our industrial group at Risley followed up with design and construction, again in collaboration with the industrial group.

During this period we invited the British Electrical and Allied Manufacturers' Association to send engineers from any firm which might be interested in designing future power reactors, and as a result three more engineers joined Harwell. We have recently started a design study on

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the second type of reactor and are arranging the collaboration of a second industrial group.

We have also been approached by aircraft firms and the shipbuilding industry which wish to be allowed to study the possibilities of applying nuclear energy, and we are doing our best to meet their requirements, although we believe these applications to be much more remote. As part of this program of industrial participation we have organized a school of reactor engineering which have courses lasting about three months. For the present this school is at Harwell, since lectures will have to be given by our own staff, and they can do this with less diversion from their own work if the school is on the spot.

We have also established collaboration with a number of chemical organizations on the plastics work I mentioned. The irradiation of plastics is being carried out by industrial groups which send their products to be irradiated and tested. The polymerization work is being developed either by using Harwell sources or by providing sources of radio-cobalt for industry and universities to use. This has followed our earlier collaboration with industry on the application of radioactive isotopes.

If we look a little farther into the future, nuclear-power stations will be designed by industrial organizations, for the B. E. A., or for export, but with the advice and assistance of the Atomic Energy Authority, which will operate the expensive central facilities for tests of reactor components and for production and processing of nuclear fuel; it will also do some of the pioneering design work.

Finally reference may be made to ship propulsion. The accounts of the United States navy's Nautilus, the first nuclear-propelled submarine, will be familiar to many readers. The power unit for this submarine consists of a water-moderated reactor using almost pure U-235 as a fuel, and heat is transferred by water at high temperature to raise steam and drive steam turbines. The power unit must therefore be bulky quite apart from the shield, and the submarine is probably about 3,000 tons displacement. Much effort has been devoted to this project. The development costs for the prototype reactor amounted to twenty million dollars. It was the most difficult project ever undertaken by Westinghouse. An essential part of the work was the development of the technology of zirconium—a metal almost new to industry. There is no doubt that we could build similar propulsion units if it were thought worth while to devote the effort and money to such a project. We are at present assisting the Admiralty in a design study of this type of propulsion unit.

INDUSTRIALIZING AUSTRALIA

Needed: Power and People . . *by M. L. Oliphant*

Canberra

THE area of the island-continent of Australia is almost the same as that of the United States, but a much smaller fraction of the land surface is suitable for food production. Over the greater part of the country the average rainfall is extremely low and is distributed erratically both in time and in place. In these regions of central and northwestern Australia there are no permanent rivers, evaporation is high, and the only dependable sources of water are artesian bores which often yield brackish water of no help to vegetation. The tropical north contains areas which could be capable of development, but it is as unpleasant a place to live in as any tropical region in the world. The principal settled area of Australia, where equable climate, reasonable rainfall, and high soil fertility are combined, is adjacent to the southeastern coast. Here, too, are good deposits of easily mined coal and considerable water-power from streams originating in the mountain ranges that fringe the coast.

Increased population, large-scale capital investments, and the application of scientific knowledge could make Australia one of the great industrial nations of the world. Australians, moreover, are becoming acutely aware that they can justify their high standard of living, and occupation of so large a portion of the earth's surface, only if they develop their country to the fullest possible extent and enable it to provide living room for a larger part of the surplus population of Europe. Australia is not an underdeveloped area in the sense in which that term is applied to Asia or the Middle East. Relative to population Australia is highly industrialized. The problem before it is to develop its resources and increase its population at a rate which has never before been achieved. This implies a large degree of self-restraint on the part of the present population in order to provide the capital development so essential for the future. The people of Australia will respond to the challenge and will make rapid progress in taming their intractable land if only they can be assured of unlimited industrial power.

Against this background the problem of power supply in Australia is different in kind as well as in magnitude from what it is in other parts of the world. In the eastern part of the country the mining of sufficient coal for all needs is less a problem of technology than of sociology. Coal-mining, even when fully mechanized, is regarded as an unpleasant occupation subject to peculiar ha-

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zards. Where man-power is short and opportunities for other forms of work are unlimited, few men want to go into the mines. Increasingly high wages make coal more and more expensive, and this, together with frequent strikes and stoppages, forces industry to seek alternative sources of heat and power. In other parts of the country the additional problem of transport renders coal either prohibitive in cost or too uncertain in delivery.

We are therefore forced to the conclusion that another source of power, free from these defects, is essential to the development of Australia. The large-scale use of imported petroleum would provide only temporary and very expensive respite. But atomic energy, derived for the immediate future from the fission of uranium and thorium, of which Australia possesses reasonable supplies, and for the longer term from the fusion of deuterium and lithium, would almost certainly meet the need. Costs of transport would disappear, so that economic power stations could be built inland far from the coasts and the coal fields, and the skilled men who mine the high-grade ore from the earth could be well paid without increasing unduly the cost of the fuel.

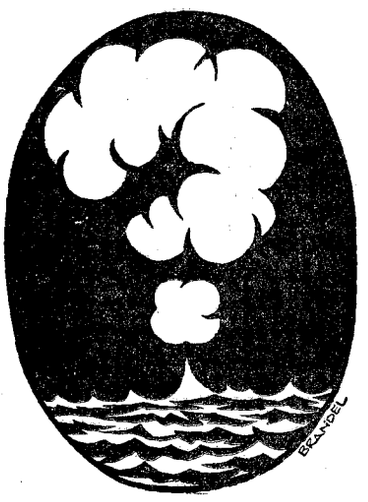
The Need for Fresh Water

The rainfall in the eastern part of Australia is probably sufficient for most needs if proper schemes of water storage and conservation are undertaken. But such projects must be bold, on a large scale, and carried out in advance of, rather than in answer to, demand. In areas which are relatively undeveloped or where population is small it might be both practicable and economic to use atomic explosives in the building of dams and the diversion of rivers.

Australia's most intractable long-term problem is the provision of water in the arid central and northwestern parts of the country. In certain areas where valuable minerals are obtained it may prove economic to use atomic energy to distil brackish or salt water in order to provide fresh water for household, technological, and vegetable-growing purposes. Fission reactors to supply the relatively low degree of heat required for distillation should be relatively cheap to build and operate. Such distillation plants might be located on the seacoast and the distilled water pumped inland by power from atomic reactors. The economics of such schemes require careful appraisal, since systems that would be unprofitable in America or Europe may have great value for the development of large areas of Australia.

An important point to bear in mind is that the distillation may be carried out in such a way as to enhance the content of deuterium in the residue. Many of us are now convinced that the fusion process may be more easily brought about in deuterium than has been generally recognized and that this element, together perhaps with the lithium derived from the salts recovered, may become a more important nuclear fuel than uranium or thorium. In that case the distillation plant and its associated power station might produce not only its own nuclear fuel but also fuel for many other nuclear-power installations in the country.

More than one-third of Australia lies in the tropics. Parts of the center and west suffer from intolerably high temperatures in the summer. Mining, grazing, and tropical agriculture languish because the necessary labor force cannot be recruited, is of low grade, or demands such high wages that projects become uneconomic. However, life in these areas becomes tolerable and even pleasant when houses and offices are air-conditioned. I am certain that the answer to life in the tropics for people of European descent is the adoption of air-conditioning on a scale hitherto undreamed of. It has been shown in India that even the native inhabitants can do more and better work in office and factory if the buildings are air-conditioned, and further advantages follow from undisturbed sleep in cooled rooms with reduced humidity.



Dependence on Petroleum

Air-conditioning is in its infancy. Costs must be reduced and equipment made more reliable before its universal use in the tropical and arid zones of Australia becomes practicable. But arguments against the ultimate solution of these difficulties are no more valid than those advanced a short time ago against the practicability of refrigeration or television for every home.

The large quantities of power required for widespread air-conditioning can be provided in these areas only by atomic-energy power plants. Indeed, careful thought about the development of these areas leads to the conclusion that most of the obstacles can be removed by the large-scale use of atomic energy and only by that means. Atomic energy is likely to prove economic in these parts of Australia long before it can compete with other forms of energy in Europe or America.

Australia possesses no proved deposits of petroleum of any importance. Yet its communications, its mechanized farming and grazing, and its industrial-development projects render it critically dependent upon petroleum products. At present crude petroleum is imported largely from the Middle East, and in the event of war the supply might well be cut off. For the present atomic energy cannot be used successfully for small mobile power units. Apart from problems of shielding, the hazards arising from accident or from unskilled handling may mean that such application must be prohibited. It seems likely, therefore, that fuels for internal-combustion engines will be required for a long time to come.

Synthetic liquid fuels, derived from coal or organic matter, are not at present competitive in cost with the natural product, but I am assured by experts that if petroleum supplies failed, these artificially produced fuels and oils could be made and used. The considerable amount of power required for the operation

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of synthetic-oil plants might have to be supplied by atomic energy. Nuclear radiations might also prove useful in bringing about some of the processes of synthesis. Thus any comprehensive review of the possible applications of atomic energy in Australia must take account of the country's critical dependence upon imported liquid fuels and the ultimate need to produce them synthetically.

Many strategic raw materials, such as copper, lead, and zinc, are not available in sufficient quantity to enable existing technologies to be applied in Australia as extensively as in the United States. Hence substitute materials become essential. Materials like aluminum, magnesium, titanium, and their alloys are potentially available in unlimited quantities. Electrochemical processes require large quantities of electric power and are usually associated with hydroelectric projects, but in Australia the limits of hydroelectric development will be reached long before the needs of the country for electrochemical products can be met. Nitrogen fertilizers are another prime need, and these can be manufactured out of the air if an ample supply of electric power is available. Thus Australia's peculiar physiographic conditions, its necessity to expand its population and to develop its resources at a rapid rate, and its desire to maintain a high standard of living combine to make it critically dependent on the introduction of a new source of power.

IRRIGATING THE NEGEV

Potential Boon for Israel . . . *by Amos de Shalit*

Rehovoth, Israel

IN ISRAEL as in many other countries the increasing demand for industrial power may some day be met with atomic energy. Countries which have no natural power sources can benefit greatly from atomic power if the cost of releasing it from atomic fuel is greater than that of producing energy from coal or oil. Savings on the transportation of the fuel may overbalance the expense of atomic installations.

Shortage of power is undoubtedly one of Israel's gravest difficulties. Without any known deposits of coal or oil, it depends entirely on imported fuels, and owing to present relations between the Arab states and Israel these imports have to be brought from as far away as Venezuela. The long supply lines, besides being very vulnerable, so increase the cost of fuels, and hence of all finished products, that Israel finds it almost impossible to compete with other countries on the international market.

Even without this supply-line problem, which is essentially of a political nature and will be solved some day, the proposed development plans for Israel and its neighbors will create such an enormous demand for energy that it is doubtful whether they could be carried out by the use of conventional fuels alone. A great part of the Middle East is desert which could become productive if water were available. There is plenty of sea water near at hand, but sea water will not do for irrigation. It can be converted into sweet water, but with present power resources use of distilled water on the land would be prohibitively expensive. A supply of cheaper energy is required.

The possibility of piping water to the desert from regions of greater rainfall has been considered for some time and is actually being carried out in the southern part of Israel, the Negev. Water now wastefully flowing down the northern rivers to the sea will be diverted into reservoirs and used for irrigation. The supply, however, is limited and going farther north to tap other sources of water would mean a great expenditure of power to bring the water down to the south. Again cheaper power may provide the answer.

All forms of energy except atomic energy are ultimately derived from the sun. The energy expended by an ox drawing a plow comes to it from the grass it eats, and this grass acquires its energy-content from the chemical reactions induced by absorption of the sun's rays. The power of waterfalls originates in the action of the sun in evaporating water from the seas, which then feeds springs in the mountains. Coal and oil are the remains of organisms that owed their life to the sun.

The uranium from which atomic energy is extracted did not acquire its energy content from the sun; it possessed this energy from the moment of its creation. The process of releasing the energy from uranium resembles the process which takes place on the sun and causes the sun to give forth heat and light. Atomic reactors are like small suns themselves, whereas conventional power plants are gadgets invented to utilize a small fraction of the sun's enormous energy.

Atomic energy has the peculiar characteristic of being about a million times more concentrated in its carrier than ordinary energy in ordinary fuels. This high concentration means a tremendous saving in the transportation, handling, and storage of atomic fuel. In fact, transportation of the fuel may be safely omitted from any estimate of the cost of production of atomic energy. Thus if the cost of transportation makes the use of conventional fuels uneconomic, atomic energy may be a practical alternative.

The actual cost of atomic power is not yet known. Guesses vary

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widely. If it turns out to be at least as expensive as the average conventional power, it will still bring relief to countries discriminated against by nature in the matter of natural resources. With its aid Israel and the Arab states can undertake development; the area around the Dead Sea, which is rich in minerals that cannot be exploited because of the high cost of fuel, can be made to flourish with new industries and new communities. It is the combination of minerals, water, and power which enables people to lead a decent life, and in places where nature has been remiss atomic energy may repair the damage.

THE ATOM IN INDIA

Searching for Sources . . *by S. A. K. Ghosh*

Calcutta

THE quantity of power used per capita in a country is the index of its development and standard of living. The per capita consumption of electricity in India, before the Five Year plan, has been only 14 kilowatt-hours, as compared to 1,100 in Great Britain and 2,207 in the United States.

Present sources of energy are coal, oil, and water-power. In proportion to its size, population, and supplies of raw materials India is poorly endowed with coal and oil—it is possible of course that some sources have not yet been explored. According to the Geological Survey of India, reserves of coal of all grades amount to sixty billion tons, of which twenty billion tons are workable and only five billion of good quality. Average production is about thirty million tons a year, with the Indian railways consuming 32 per cent of the total. India's good coal is confined to Bihar and West Bengal, except for small seams in Assam and Hyberabad, and because of the distance of the fields from industrial centers its use for the generation of power is very costly. Modern methods make it possible to utilize the low-grade coal found in some districts of southern India for steam generation, but its use would be economic only in nearby areas.

As to oil, the Assam oil field produces 5 per cent of India's requirements, the rest has to be imported.

Potential hydroelectric resources are vast. They have been surveyed and may amount to as much as forty million kilowatts, but they have been tapped so far for only a half-million kilowatts.

At the present low rate of consumption of coal in India it is estimated that the supply will last about six hundred years. But if the rate of consumption should be increased to something comparable to Great Britain's, Indian reserves would be exhausted in two hundred years. Thus to achieve the industrial development that would appreciably raise the standard of living some other source of power must be harnessed.

In 1948 the government of India appointed an Atomic Energy Commission, one of whose tasks was to discover whether the country possessed the raw materials for the production of atomic energy. The commonest source of uranium, pitchblende, in not found in India, but monazite, which contains some uranium and is extremely rich in thorium, exists in considerable quantity in the black sands of Travancore-Cochin. The government has therefore set up a plant at Alwaye in Travancore to process some 1,500 tons of monazite a year. The decomposition of monazite is carried out with caustic soda. In 1951 India was producing 1,400 tons of caustic soda annually; the goal set in the first five-year plan was 33,000 tons. Since hydroelectric power is available, annual production may be raised to 87,000 tons. The thorium produced will be adequate for the needs of atomic research.

India possesses an abundant supply of graphite, which is used as moderator in an atomic-power reactor. Several factories have been started by the government to free the raw graphite of boron and make it suitable for use in a reactor.

The greatest obstacle to the utilization of atomic power in India is the lack of technical training. With steel and aluminum practically the only metallurgical industries, the knowledge and skill necessary to extract thorium from monazite, purify graphite, and build a reactor have been developed in very few persons. Here is where more advanced countries can give essential aid.

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The Revolution Against Starvation

It is indeed a heathen hope that invests $1,500,000 in the food and agricultural work of the United Nations; 1,000 times this in arms to Europe; and 16,000 times this in military "defense" It is indeed a heathen hope that welcomes the illusory advantages of the Fusion Bomb and asks only to know that it is a bigger and better bomb.

No war, cold or hot, can be won unless the hearts of men are mobilized by enduring human ideals. Disturbing as it may be to our pleasant status quo, a revolution is aflame through all the backward and populous areas of the world—a revolution against starvation, poverty, exploitation without representation. We can help to lead this revolution (as we too were once revolutionaries); or we can oppose it; but we cannot long prevent it.

David Bradley at The Nation's forum on The Atomic Era, April 29-30, 1950.

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III. THE USES OF THE ATOM

The "mass attack" on the secrets of the atom—David O. Woodbury's excellent phrase—is constantly opening new paths for the scientist and resulting in an ever-broadening field for the application of atomic energy and of the processes connected with its manufacture. Mr. Woodbury sketches the general picture with emphasis on chemistry and engineering. Dr. Jacob Sacks details the progress made in medicine, biology, and biochemistry. Atomic science promises that we can live longer in a better world.

SURVEYING THE FIELD

The Limitless Potential . . *by David O. Woodbury*

THE great hurdle that the atom must leap in order to win public confidence as a force for peace is the evil it has done. Ten years ago atomic energy clutched the world with the gigantic hand of destruction. Millions everywhere watched, fascinated, as the first atomic bomb became "conventional," then ordinary, then outmoded by the overwhelming might of the hydrogen bomb. Splitting the atom spelled the final unanswerable threat to civilization.

What a start for a discovery that may end mankind's ten-thousand-year struggle upward out of darkness! Did any comparable advance ever first destroy and then beg for trustful acceptance? Horrible as the bomb was in use, terrifying as it may still be in prospect, its flames consumed a thousand little candles of progress that might have glimmered for years with pale results and, in so doing, lighted up the vast area for achievement that lies ahead.

America's development of the atomic weapon broke every rule of scientific procedure. Thousands of men and women were commandeered into a research that many of them feared and mistrusted. They did this under extraordinary restraints of secrecy. They demanded billion-dollar factories for making substances not mentioned in the most advanced textbooks, backing their decisions with evidence often too tenuous to be susceptible of thorough test. They telescoped into five short years a work that should have taken fifty or a hundred.

But they won. It is fair to say that if atomic energy had not been revealed and reduced to practice in this headlong fashion, our present generation, the next, and perhaps the next after that would have gone without the benefits of this wondrous new power. Many of those benefits are matters of fact today; many more crowd upon the scene so fast that there is not newsprint enough to report them.

The New Mass Attack

These great benefits will not be confined to the uses of the atom itself. The method by which nuclear forces were discovered has had a profound effect on all science. It has taught us the virtue of a mass attack upon nature's problems. We are emerging into a wholly new climate of discovery and application. I have no doubt that the magnificent achievement of Salk was hastened by the new "task-force" philosophy of research.

Formerly we edged into the solution of new problems in the quiet sanctity of laboratories staffed with dedicated people who recognized no urgency. Now we march upon these problems in organized ranks, bringing every possible combination of talent, money, and public support to the battle line. Today we can put pressure upon areas of scientific doubt and obscurity that nature cannot withstand. Scientist and engineer are the same, but they move with new confidence, new will to accomplish. It is in the light of this philosophical new day that I want to interpret some of the advances already made and look ahead to others still only on the horizon. Let us start with a small isolated case—the story of the obscure element known as thulium.

In the course of a systematic search for basic facts concerning little-known substances, a research worker at the Argonne National Laboratory found that one artificial form of thulium, the radioactive isotope 170, gave off X-rays instead of the usual alphas, betas, and gammas familiar to uranium hunters. A useless bit of knowledge suitable for the technical journals, perhaps? No. Within two years there emerged from it a small package hardly bigger than a lady's handbag capable of producing X-rays of 100,000-volt energy *anywhere*. Portable, inexpensive, independent of outside power source, this little device can be taken by a doctor on his rounds for quick X-ray examinations in the home. It can jump to the battle front to help locate the steel in wounds and show up broken bones. It can spot tuberculosis in people in remote areas where no heavy X-ray unit can go.

Take another small example that may loom large very soon. A team of plant geneticists at the Brookhaven National Laboratory has been working for some time on the new science

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DAVID O. WOODBURY, author of the just published "Atoms for Peace," has interpretea scientific progress for the layman in many books and articles. Another of his books, "Total War or Total Peace," written with Tom Slick, will appear this year.

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of atomic mutations. Seeds are carefully exposed to radioactive cobalt, then planted and grown. In this strange new garden the plants come up monsters—stunted, weak, sterile, malformed. But once in a while a mutation is produced that is not abortive. The tiny genes within the seed, disarranged by the atomic blows, realign themselves into strong healthy bits of hereditary substance. The resulting plant may be a wonderful improvement upon anything that has gone before. Then the thousands of failures are thrown away and the bright new discovery is nurtured to become the ancestor of a new plant family.

Normally mutations occur over a long passage of time. The atomic method can produce such an enormous number of mutations that the frequency of good results is greatly increased. The Brookhaven Laboratory, using the seeds of the oat plant, produced in little over a year a brand-new species, resistant to the oat's greatest fungus enemy, rust. Potatoes cannot be stored over the winter, unrefrigerated, without sprouting or rotting. At the University of Michigan, in a government-sponsored research project, a simple atomic answer is being made ready. Treating new potatoes with a small dose of radiation from specially prepared cesium, a rare metal, prevents them from rotting or sprouting for years. These are random examples taken from the agricultural atomic front, which is expanding every day.

The Refrigeration Field

Spearheaded by the army's quartermaster corps, researches which may ultimately make most refrigeration unnecessary are driving forward in many laboratories. The new idea is complete sterilization by irradiation with atomic particles. If the treatment is carried out after the food has been hermetically packed, all bacteria will be killed and no more can get in. This suggests that meats, vegetables, and staples can be stored on pantry shelves, that fruits can be kept smooth and fresh for months, that loaves of bread will not mildew, even that wines and liquors may be aged in a few hours into high-grade products. These things have not happened yet. There are serious problems of impaired taste and color and of cost. The point is that the task-force method can be expected to overcome the difficulties.

Great things also are doing in the new field of "hot" chemistry. Here we can only peer over the shoulder of the experts, hard at work on the problems of building and rebuilding molecules they can never see. Atomic radiation introduced into a chemical reaction may give as startling results as the cry of "Fire!" in a theater. The atoms may begin plunging about in panic, entirely forgetting their ordinary behavior. Complete strangers among them may cling together; old friends may split up and abandon each other. New compounds can be made; old ones can be built in seconds where once it took weeks or months.

At the present moment chemists don't yet know what they can do with these strange new "souped-up" reactions. It seems to have great potentialities in the refining of petroleum. At the present rate of consumption the world's known supply of petroleum and gas is not expected to last more than a few decades. But now comes the possibility that gasolines and oils may be built artificially out of plentiful oxygen, hydrogen, and carbon in an atomic environment. And along with them a host of organic compounds—plastics, dyes, textiles, drugs, perhaps the foodstuffs on which we live.

In a quieter branch of the field—plain radio-chemistry—incredibly delicate radioactive materials known as "tracers" are being used in every laboratory to penetrate into the ultimate mysteries of the structure of the material world. The tracer is an atomic tool, a tiny group of common atoms made active in special government reactors at Argonne, Oak Ridge, and Brookhaven. The most delicate weighing device in the world can measure down to a hundred-billionth of a gram. By "doctoring" a sample to be weighed with a minute but known quantity of the common and inexpensive tracer, radiocarbon, a simple radiation detector can measure as little as one-trillionth of a gram with high accuracy. Some of the new detergent oils for cars came from research dependent on these tracer studies. The latest ideas about friction and wear and how to stop them in the millions of rubbing surfaces found in

our machinery depend on the measurement of micro-quantities that only atomic sleuths can make.

Solving Medical Problems

Or take medical research. What is the hope of arresting cancer at its source by preventing the conditions that favor its growth? Why do hearts fail, arteries stiffen in old age, livers and kidneys and the hidden body glands suddenly stop their orderly functioning? Until now, with the best tools the laboratory could buy, the scientist has been able to get no closer view of intimate bodily activity than a baseball fan could get of a game played on the moon. But out of the furious interiors of the machines that made the bomb come thousands of little radioisotope tracers that enable scientists to carry on their experiments at close hand.

Already some small part of the knowledge gained in the ten years since Hiroshima has been utilized in curing, treating, and diagnosing ailments that have remained obdurate for centuries. So rapidly is this new knowledge paying off that anyone with at least ten years of normal life expectancy left can hope that some of the ills he dreads will be eradicated before he succumbs to them.

Atoms made radioactive in the atomic pile still behave in all essential (chemical) ways like normal atoms. Thus they can be mixed with their own kind and used as "tags" to reveal how common substances migrate and interact, even though such activity is far below the threshold of the best microscope or weighing balance. In a Canadian project, for example, fish food has been tagged with radiocarbon and dumped into lakes to see how thoroughly it will spread. So detectible is the material that if a single teaspoonful of the

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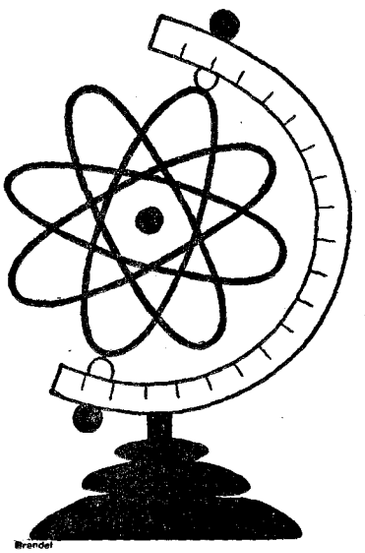
radiocarbon were dumped into Lake Ontario and allowed to disseminate completely, traces of it could still be discovered in any teaspoonful of the lake water months later.

Dr. Willard F. Libby of the University of Chicago, now of the Atomic Energy Commission, has used the radioactive carbon isotope to determine the approximate age of any object containing carbon, back as far as 20,000 years. All growing things, he has found, contain a minute but predictable quantity of radioactive carbon absorbed from the atmosphere during growth. By a detection system thousands of times more sensitive than the best Geiger counter he can measure the faint radioactivity remaining, say, in a bone or wooden arrow found in an Indian digging and tell within a few decades how long it has been lifeless material. Thus we have a new and independent method of checking man's earliest history.

Concentration of Power

Exploding atoms not only perform the world's most delicate measuring jobs but produce the greatest known concentration of power. One pound of uranium-235 has the energy of three million pounds of coal. This was one of the first discoveries made by atomic research but has been the slowest to be developed for peaceful purposes. The delay is due to the extreme difficulty of control and the enormous expenditure in time and money required to perfect the apparatus. Since most of our common structural materials cannot stand the intensity of the atomic-fission reaction, progress had to wait till a whole new family of metals, fluids, and ceramics could be prepared and put into production. There was also the prime necessity of protecting human beings from radiations millions of times as strong as anything ever released before.

Ten years ago many experts predicted that atomic power would not be known in our lifetime, perhaps not in our century. The difficulties then seemed insurmountable. Today atomic reactors are springing up in many parts of the country. Pittsburgh will have the first in the public-utility field—a small giant of 60,000 kilowatts—New England soon after. After that a veritable Gar-



gantua of a plant will produce hundreds of thousands of kilowatts for New York City. Fortunately, the early steps toward peace-time uses of atomic energy could be taken parallel with the weapons effort, without much diversion of talent or extra cost. The atomic reactor which produces plutonium fuel for bombs can also turn out power. It is a relatively simple matter to design a similar one that will furnish heat and hence be capable of driving turbines and generators. In fact, both functions can be performed by a single machine, as will be done in the great power reactors of the future.

The technical problems of peaceful power have been studied and mastered by group effort—an extension of the magnificant teamwork that achieved the first enormous release of atomic energy. The original teams have been constantly reaching out and inviting more and more qualified people to join with them in the work. A few years ago a small, secretive inner circle possessed all the knowledge and was severely restricted by federal law—the old Atomic Energy Act—from divulging it to anyone. Today increasing numbers of engineers, scientists, chemists, metallurgists, and experts in a hundred fields are beginning to share in the basic findings and are eager to contribute their own new ideas. The principle of mass attack upon the problem of atomic power has been put into effect. The stated aim of the Atomic Energy Commission, under the act of 1954, is to bring to bear on atomic energy the greatest concentration of American initiative ever lined up on a problem.

A spectacular achievement is the famous atomic submarine, the Nautilus. Through the dogged persistence and courage of Admiral Rickover and his little band of assistants, the navy was induced to make the experiment which sent the small ship to sea. Today it is a success beyond anyone's fondest hopes. Other types of naval vessels are now planned, and the merchant marines of the United States, England, and Norway are considering the possibilities. The President has called for the building of a good-will atomic vessel to travel around the world, without refueling, so that all may see how it is done.

The Question of Cost

An atomic locomotive has been designed, a group of carriers having obtained A. E. C. approval for a study of how the new motive force can be applied to railroading. Meanwhile, the first portable atomic-power plant is being built, and the first plane to fly with nuclear power is in the mock-up stage.

Industries of every kind have embraced the atom, both as a means of delicate control and as an unmatched source of energy for massive manufacturing requirements. In the chemical industry, for instance, huge quantities of heat are needed. Plans are under way to build atomic machines which can meet the industry's needs. Cities, institutions, isolated mining ventures are all beginning to look to the atom to supply their power needs. One very interesting avenue of experimental application will be the transformation of sea water into fresh.

Spurred on by the gathering enthusiasm, a revolution within a revolution has started at the Knolls Atomic Laboratory in Schenectady, New York. The goal is a new design for an atomic reactor which will cut in half the weight of the machines now considered the most advanced. Here is independent initiative at its best.

But in all this imaginative rush we must not lose sight of the basic fact that no new form of energy will win acceptance until it is at least as economical as the fuels now in use. It is here that the value of a central development agency like the Atomic Energy Commission is most appar-

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ent. The great lag between the invention of an important new device and its widespread use has often been due to its uneconomic position in infancy. Somebody has to stand the strain of development—the painful years of testing and improvement. For relatively small things like the telephone, the automobile, or the airplane small groups can manage. But for a gigantic advance like atomic energy no one can support the pioneer work but the people themselves. The A.E.C., as the people's representative, has performed this function and has brought atomic power to the point where it can begin to compete with older forms of energy.

We are not quite there yet. The huge plant now going up at Pittsburgh cannot generate electricity at anything like the low cost of Pittsburgh's conventional plants. Nor will the great station to go into service in New York some years hence. Both will be gambles by their owners—not the public—taken in the belief that real advance can only come through practical trial. Economic operation will be the hardest nut to crack of all.

In some places, however, atomic power has a clear economic advantage even now. These are the out-of-the-way places where ordinary fuel is prohibitively expensive. In Greenland, for example, where half the freight load to supply the weather and military stations must be fuel, the atomic reactor will go into service immediately. One plane can fly in enough uranium to keep a small plant going for a year. Similarly, in underdeveloped countries with no power at all, where men do everything by their own muscles, agencies of our government and of the United Nations plan to establish portable atomic stations to help raise the living standards of the people. There are even areas in this country whose remoteness rules out the full use of electric power. Atomic stations bringing heat and light and motors will make life much easier there.

Man's Labor

The promise of atomic energy is tremendous, but it will not create a utopia in which fingers need be lifted only to push buttons. Nor should we want it to. If ever we find an agency that will take all burdens off humanity, civilization will disappear. In atomic energy lies the hope that man can work more effectively, with greater inspiration, and in greater peace. With this new tool, and the sharpening of the wits and the imagination which its use will stimulate, he can go on into a rapidly widening circle of discovery. He has only begun to find out how to live with himself and his environment. The atom has more to give humanity by its inspiration than by its direct gift of emancipation from work.

The most foolish denial of man's purpose on this earth is to say that he can do no more, can learn no more, can imagine no more. Twenty years ago the world's most skilful scientists said that the power of the atom appeared to be beyond realization. They could set down figures to prove it. Today atoms are at work in every hospital; atoms are driving turbines to make light and propel ships. In schools and colleges all over the world these achievements are being explained to youth, inspiring them to a new kind of thinking, generating in them a new daring. Never was there a time of greater vision and greater hope than the present, the dawn of the Atomic Age.

THE ATOM IN MEDICINE

Revolutionizing Research . . *by Jacob Sacks*

THE WORDS "isotope" and "radioactivity" became a part of the vocabulary of the average intelligent person only in the aftermath of Hiroshima. But ten years earlier biochemists and other biologists had already began to use radioactive isotopes as tools in their investigations of the chemical processes constantly taking place in living matter. By the time that nuclear fission was discovered and a small group of physicists, all refugees from the totalitarianisms of the Right, had seen dimly in this phenomenon the possibility of the atomic bomb, medical researchers were laying the groundwork for the use of radioisotopes in the diagnosis and treatment of disease. The radioisotopes they used came mostly from the operation of the cyclotron, the atom-smashing machine invented by Dr. E. O. Lawrence of the University of California. These pioneer workers had only very small amounts of isotopes, produced at a cost so great that the whole operation would have been impossible in a budget-minded setting. The instruments used for measuring radioactivity were mostly home-made, barely adequate for the task.

Today the research worker or physician who has demonstrated his competence in the use of radioisotopes—frequently by having taken a training course at the Oak Ridge Institute of Nuclear Studies—need only send a routine purchase order to the Isotopes Division at Oak Ridge to obtain in highly concentrated and chemically pure form any quantity of the radioisotopes he needs. The Oak Ridge nuclear reactor—once only a pilot plant for the giant reactors at Hanford which today make our atomic bombs—can produce practically all the radioisotopes needed for research

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in the United States with enough left over for some export. The price is fantastically low. As for measuring instruments, the scientist can make his choice among the products of a number of manufacturers operating assembly lines.

The primary object of the biochemist who uses radioisotopes is to uncover the processes by which body cells build their structures, the mechanisms by which they convert food materials into these structures, and the manner in which they utilize the food materials both as building blocks and as sources of energy. Isotopes are useful as tracers because their radioactivity enables them to be followed through all their complex chemical transformations in the body. The chemical properties are completely independent of whether the isotope is radioactive or stable.

Schoenheimer's Experiments

The first important use of isotopes as tracers was made by the late Rudolf Schoenheimer at Columbia University three years before the first radioactive isotope was produced in the laboratory. Schoenheimer used the heavy stable isotopes of hydrogen and nitrogen which his colleague, Harold C. Urey, had succeeded in separating from their higher stable counterparts. Using heavy hydrogen, called deuterium, as a tracer Schoenheimer was able to show that the "depot fats" of the body, which had been considered to be in inert storage, were used as sources of energy, being partially replaced daily by fats taken in as food. Using heavy nitrogen as a tracer, he was also able to show that the proteins of the body are in the same dynamic state; part of the proteins of the liver, muscles, and other body tissues is burnt up every day for energy and replaced by an equivalent amount of diet protein. The principles underlying the use of the heavy stable isotopes as tracers are the same as those later put to such broad use with radioisotopes; the techniques for measurement are different.

Schoenheimer's findings revolutionized biochemistry. Previously it had been considered that the body structures were relatively fixed, that there was no mixing of food with structural materials. During growth, of course, food had to be drawn

upon to build body cells, but apart from that and the replacement of worn cells by new ones, there was supposed to be this sharp line of separation. The change in the biochemist's viewpoint is so complete that he now takes it for granted that everything in the body is in flux. When experiments with radioactive phosphorus showed that the bones themselves are constantly changing, that every half-hour about half the phosphorus atoms circulating in the blood plasma change place with phosphorus atoms in the bones, the results were accepted as a matter of course. Only one significant exception has been found to this dynamic state—the molecules of the hemoglobin in the red blood corpuscles which carry oxygen to the body cells and take carbon dioxide away from them. The corpuscles, produced in the bone marrow, have a life span of four months. Tests show that the same atoms of carbon, hydrogen, nitrogen, oxygen, and iron that make up the hemoglobin molecule when the red blood corpuscle starts out are still there when it dies.

All these studies on the body's chemical dynamics are interesting to the scientist, but in this pragmatic world the plea is always for the practical application of knowledge. Well, the pragmatist has been served, and frequently with very little time lag. In 1939, a group at the University of Rochester, under G. H. Whipple, published the results of a study of the utilization of iron for the formation of hemoglobin. With the help of a radioactive isotope of iron, they were able to demonstrate that the body absorbs and utilizes the iron in the food only as needed when body stores have been depleted. Shortly after, the government's Office of Scientific Research and Development was confronted with the problem of "banking" blood so that instantaneous transfusion on the battlefield would be possible. The great danger was that the red cells in the preserved blood, although they might appear normal under the microscope even after a considerable time lapse, would not survive the transfusion. Disintegrating in the blood stream of the recipient, the red cells would liberate hemoglobin, blocking the kidneys and possibly causing death.

The O. S. R. D. commissioned two groups to study the problem with the help of radioactive iron. Medical students were injected with the isotope. After several days, the radioiron was present in their newly formed red blood corpuscles. The blood was then drawn, different parts treated with various preservatives under a variety of conditions, and stored for different lengths of time. Now small amounts of the samples of stored blood were injected into the veins of other volunteers, samples of their blood drawn at frequent intervals for the next few days, and the radioactivity measured. The use of the radioactive isotope made it possible to use such small quantities of blood for the tests that even where the transfused cells did not survive, no harm was done. In each case the radioactivity measurements revealed what fraction of the transfused blood corpuscles had survived and were carrying out their function. The result: methods for preserving blood were worked out which made possible the tremendous blood-bank operation of World War II. Since the war the "blood bank" is standard equipment in modern hospitals.

Studying the Thyroid

Another example of turning the results of "pure science" investigations with radioisotopes to practical utility is in connection with the workings of the thyroid gland. This gland, located just below and to the sides of the Adam's apple, regulates the metabolic level of the body by means of compounds which contain nearly all the body supply of iodine. In 1938, two medical-research groups started to use radioactive iodine to study various aspects of the gland's functioning. Today most large clin-

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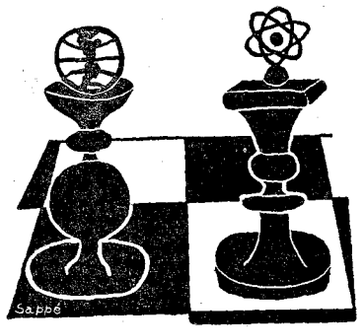
ical groups and many of the larger hospitals use radioiodine constantly for the diagnosis of thyroid disorders. Oak Ridge makes more shipments of radioiodine than of any other radioisotope. Most is used for diagnosis, the rest for treatment of thyroid disease.

Agricultural experiment stations use radiophosphorus extensively in studies that are on the borderline between science and technology. A



vast program of research, made feasible by the radioisotopes, has demonstrated how best to use phosphate fertilizer for corn, potatoes, sugar beets, tobacco, and a wide variety of other crops. And this program is continuing, adding to the sum total of information that makes for efficient farming and the better utilization of natural resources. Such studies help postpone the day when growing populations will overtake the potential food supply.

Special Therapeutic Uses

We live today in the shadow of annihilation by the H-bomb; some qualified observers have expressed fear of the possible long-term genetic effects of the radiation liberated in the testing of nuclear weapons. These fears are based on the known biological effects of radiation from radioisotopes. These are the radiations which make isotopes valuable as tracers in the type of experimentation we have been discussing. The *controlled* use of such radiations, using X-ray and radium as sources, has been a valuable aid in medical diagnosis for almost sixty years, and in the treatment of cancer and certain other diseases for about half that time. For the most part, the substitution of man-made radioisotopes for high-cost X-ray machines and radium represents nothing new in principle. It is just a matter of making the radiation tool much cheaper and, for that reason, more widely available.

There are two good examples of the use of radioisotopes in special cases of disease. One is the condition known as *polycythemia rubra vera*, characterized by an excess of red blood corpuscles which choke the capillaries and thus impede circulation. When the patient is given water containing the correct dose of radiophosphorus, a fair share of the isotope is picked up by the marrow cells which produce the corpuscles. The radiation reduces production to normal and the symptoms of the disease soon disappear.

The other special case deals with disturbances of the thyroid gland. Over-activity of this organ is encountered fairly frequently; tracer doses of radioiodine are commonly used in the diagnosis of the condition. In most instances satisfactory treatment can be provided by drugs, surgery, or both. However, there are cases in which the drug cannot be tolerated, or is ineffective, and in which surgery cannot be carried out without great risk to life. These patients can be treated with fairly large doses of radioiodine, the radiations of which destroy the thyroid cells. By proper dosage the destruction of the gland can be carried to the point where its function is restored to normal. The process takes place gradually, without severe strain on the patient.

Even more dramatic is the use of radioiodine in the treatment of cancer of the thyroid. Like cancer of any other organ, thyroid cancer spreads to other parts of the body. In a certain percentage of the cases, it has been found that when the primary thyroid cancer is removed surgically the secondary cancers, which pathologists call metastases, will collect iodine in the same way as normal thyroid cells. A tracer dose of radioiodine is given, and the Geiger counter is used to see if the metastases have collected the iodine. If so, then a large dose of radioiodine is given and the radiations destroy the cancer cells that have collected the radioiodine. Unfortunately, only a minority of cases can be treated this way; more commonly the metastases have strayed so far from normal thyroid function that they have lost the ability to collect iodine. And it must be emphasized that cancer of organs other than the thyroid cannot be treated in this way at all.

Cobalt-60, the radioactive isotope of cobalt, came into use a few years ago as a substitute for radium. A gram of radium costs about $25,000; the equivalent amount of cobalt-60, in terms of radiation, costs $100, with a substantial discount for larger quantities. This is not quite as great a price advantage as it seems, since the equipment for storing and handling the radioisotope is just as elaborate and expensive as that needed for radium. Moreover, cobalt-60 activity is reduced by half in a little over five years, whereas radium takes about 1,600 years to be reduced to half its original activity. Still, the cost advantage remains.

Development of Cobalt-60

More recently, powerful cobalt-60 installations have been introduced as substitutes for the high-powered X-ray machine used in the treatment of cancer. Here there is considerable saving both in installation and operating costs. The high-voltage X-ray machines consume enormous amounts of electricity, which is an annoyance to the user, and interferes with TV reception, which is an annoyance to the neighbors. The cobalt-60 apparatus consumes no electricity and does not affect TV reception. The drawback to the new therapy units is the tremendous numbers of neutrons needed to pro-

Herblock in the Washington Post

"If you could just control your inventions, huh?"

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duce the cobalt-60. Production methods are such that if Oak Ridge attempted to satisfy the demand for cobalt-60 there would be a decided reduction in the number of neutrons available for the manufacture of other radioisotopes. If it were done at Hanford, there would be a corresponding reduction in the amount of plutonium produced for our stockpile of atomic bombs. So the cooperation of the Canadian reactor at Chalk River, Ontario, has been obtained. This reactor, which uses heavy water instead of graphite to slow down the neutrons, makes available about ten times as many neutrons per second to convert the same sized wafer of ordinary cobalt-59 into cobalt-60 as does Oak Ridge. Again, the operation reduces the number of neutrons available for other purposes. A study is now being made of the use of another isotope, caesium-137, as a substitute for cobalt-60 for therapy units. But this isotope, a waste product of nuclear fission, presents a serious problem in disposal on account of the large amounts formed and the relatively long radioactive half-life of 37 years.

Another promising development is the recent invention of a portable machine using the radioisotope thulium-170 as the radiation source. This isotope must be made in the reactor by using up neutrons, as does cobalt-60. It needs no electricity, and can function in the open field. At the moment the primary interest is in the possibilities for use by the military, but there is a potential field of usefulness in times of peace.

Future Patterns

What of the future of atoms-for-peace in biology and medicine? Investigations of the mechanisms of the processes that take place in living matter will continue. Two possibilities deserve special mention. The daily press has made us aware that radiation can produce mutations, most of which are undesirable. This is what has aroused the geneticists to protest again the continued testing of nuclear weapons. But mutations are not always for the worse; a very small percentage have some desirable properties. For example, the commercial production of penicillin was made possible by the use of radiation-produced mutants. A

fair amount of work has been done, and much more remains to be done, in the direction of obtaining desirable radiation-induced mutants of many crops of economic importance. The road will be long, there will be hundreds of failures to one success, but the quest will be worth while.

The other possibility involves the effort to conquer cancer. Nutritionists have found that folic acid, one of the B vitamins, is essential for the normal production of blood cells. The part played by this vitamin was elucidated by tracer experiments with radioisotopes. Then the medical-research workers took over. It is known that a chemical compound closely resembling a vitamin in structure is frequently capable of playing dog-in-the-manger and preventing the vitamin from performing its function. The search began for such a blocking agent for folic acid. One was found, again by the use of radioisotopes. This substance, named aminopterin, was tried out on mice suffering from leukemia, a cancer-like condition of the bone marrow in which enormous numbers of white blood cells are produced. The experiments proved promising, so trial was made on some children suffering from the same fatal disease. The drug seemed to hold the disease in check for some weeks, but ultimately the malignant process found a way to by-pass the aminopterin and the inevitable outcome followed.

Meantime a research team at the Sloan-Kettering Institute in New York City was carrying out extensive radioisotope-tracer experiments on the mechanism by which all living cells form the substance known as desoxyribose nucleic acid, usually abbreviated to DNA. DNA is the fundamental constituent of the chromosomes, the carriers of hereditary characteristics. The institute's findings formed the basis for the synthesis of some structural analogs of one compound which is an essential building-block of DNA. Again, the use of radioactive-tracer isotopes showed that one of these, the chemical name of which is 6-mercaptopurine, was able to block the formation of DNA and thus stop the growth of tumor cells. The effect could be achieved in some types of tumor with doses that did not interfere seriously with the normal body functions. One type of tumor was caused to disappear; others were slowed down in their growth.

So far these experiments have been carried out on animals and the results obtained have given hope rather than promise. If the goal is achieved, and a chemical means of controlling cancer does come about, no small share of the credit will go to fundamental scientific research with radioisotopes. If the hope is fulfilled, there will be many more lives saved by this means than were snuffed out at Hiroshima and Nagasaki.

Cost of Atomic Power

In view of the considerable interest aroused by the announcement of Britain's ten-year plan for atomic-power stations, we repeat that the estimated cost of electricity per kilowatt hour from Britain's first commercial nuclear stations will come to six-tenths of an English penny (7 cents). This is about the same as the probable future cost of electricity generated by the new coal-fired stations being built in Britain.

Both the above estimates are based on a number of assumptions set out in the British Government's White Paper, including an estimated value for the plutonium which will be produced as a by-product at the nuclear power stations.

Bulletin, British Information Service, February 1, 1955.

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IV. THE ECONOMICS OF THE ATOM

The atom, for all its limitless potential, is essentially a fuel in competition with other fuels—water power, coal, and oil. How well can the atom compete? How soon, and under what conditions, will a major industry be created out of nuclear science? Gunnar Randers here discusses the problem in world-wide terms, while Isard and Whitney focus on the United States. Both articles were written with a realistic eye to the profit motif underlying Western society and to the fact that use of the atom needs high skill.

PATTERN OF DEVELOPMENT

Costs versus Needs . . *by Gunnar Randers*

OUR whole civilization today is built upon energy consumption. We no longer have to spend all our time in getting food and shelter. Every man can now get those things very easily and can devote most of his time to other purposes. That is because we have energy to produce aluminum and steel, to propel our aircraft and our ships, to heat our houses, to mine new minerals, to pump water for irrigation, and to do a thousand other things that formerly broke men's backs.

The relationship between energy consumption and living standards is very close. In the United States the total energy consumed is about 8 tons of coal per year per head; in the United Kingdom, about 4.5. (In "tons of coal" I include all kinds of power, converting them into one unit for purposes of comparison.) Norway also consumes about 4.5 tons per year per head, but Denmark only 2 tons, though the living standards of the two countries are almost identical. The explanation is that Denmark lives to a larger extent on agricultural production. Australia, with a mixture of agricultural and industrial production, uses 3.5 tons of coal per head; Japan, less than 1 ton, India only about 0.1 of a ton.

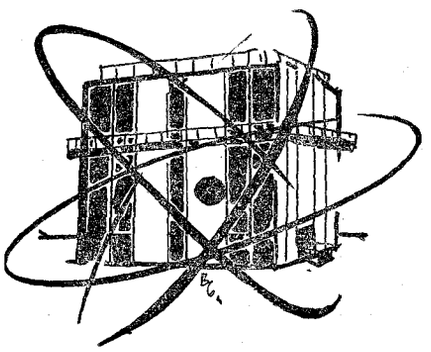
To indicate the standards of living in the countries mentioned, I will use the national income per head as a measure. (Giving it for all countries in dollars means I am not using a perfect measure, since prices vary, but it will do.) In the United States the annual income per head is about $2,000. In the United Kingdom, where the figure for the consumption of energy is 4.5 as against 8 in the United States, the income per head goes down from $2,000 to $1,000. In the light of the difference in prices that is a close correlation. Norway's national income is also roughly $1,000 per head, just as the figure for power consumption was the same as for the United Kingdom. The income figure for Australia is the same, though its power consumption is slightly lower owing to the emphasis on agriculture. Denmark is in the same class. In Japan, where power consumption compares with that in the United States roughly as one to ten, the national income goes down proportionately, from $2,000 to $200. In India the national income per head is around $50, which again corresponds pretty well to the consumption of energy.

Today for the first time in history an intensive effort is being made to raise standards of living all over the world. But raising standards of living is dependent on technical development, and technical development is dependent on the consumption of coal. We ask, then, how long coal will be able to sustain the necessary expansion? And we discover that if we really go in for a program to give the whole world an income of $2,000 per head, available coal deposits will not last twenty years.

Atomic energy, therefore, seems to be our only alternative to a declining standard of living for the world. In known supplies of uranium we have between twenty-five and fifty times as much available energy as in coal.

Atomic-power production, it should be understood, is not to be considered a new technical development, a new invention of any kind; it is a new type of fuel. Its use is a revolutionary development, for the concentration of energy in this fuel is from one million to ten million times the concentration of energy in any of the conventional fuels. All these—coal, oil, dynamite, wood, or anything else—yield roughly the same amount of energy per atom involved and have for thousands of years. Some burn faster than others, but the energy per gram is the same. Uranium and thorium, however, produce in nuclear reaction about ten million times as much per gram. Obviously, such a fundamental difference must have far-reaching effects on our civilization.

Atomic power is produced today by using the heat given out by uranium in a chain reaction to heat some kind of fluid or gas and by that means to run a turbine. The turbine will generate electricity.



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Thus the novelty is in the fuel and furnace which provide the heat. The electricity-generating equipment remains the same.

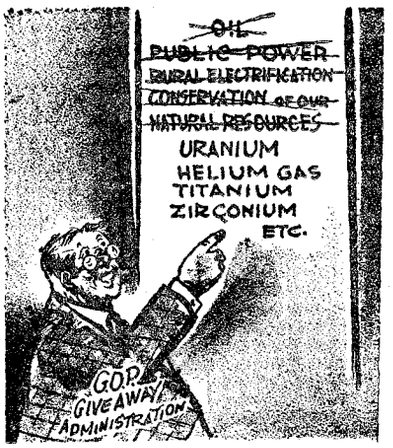
As everyone knows, it is technically feasible today to build reactors that can be used to produce electricity. The great question is: can we expect the price to be competitive with other energy sources? During the past year lots of calculations have been made to find out how the price of atomic power is affected by the price of uranium, moderating cost, the size of the reactor, its location, and so on. The conclusion has been that the price of atomic energy per kilowatt hour in any country will be exactly the same as the price of other sources of energy in that country. It may be that the calculators are not completely unbiased: they probably want that answer, and quite often one can see where the little adjusting factor comes in. But it is usually impossible to protest against the factor because the uncertainties are so large.

I think that the question of price will not be very decisive in the future of atomic energy. The price will be low enough to make it feasible to use it, and it will not be significantly lower than that of other forms of energy—until, of course, other sources of energy are really running out.

High Cost of Energy

In many areas in the world today the cost of energy is high. It is in England, which has a very courageous atomic-energy program. Most industry in England pays about one cent per kilowatt hour for electricity, and the British believe that atomic energy might lower the price. Consequently, in the next five years they intend to build plants with an installed capacity of something like 400,000 kilowatts for electricity production. This is not very much, but it represents a serious effort. In the United States four industrial firms have suggested building plants for the Atomic Energy Commission to produce roughly the same amount of electricity in the next three, four or five years—that is, 400,000 to 450,000 installed kilowatts.

To say that the British program is courageous is true in a way. But even if it were to fail utterly, it would not have cost more than twelve shillings per person per year. This would obviously not ruin the United Kingdom. Of course a program of the same size in this country would be even less risky. I am now excluding military applications, which are immensely more costly but which pose an altogether different question.



York Gazette and Daily

Hurry—While They Last

That atomic energy can be used for propulsion purposes has already been proved by an American submarine. It can obviously be used in merchant ships but will probably be considered practical only for certain types. The over-all cost of atomic power depends upon the cost of operating the reactor and the size of the investment. Since the investment required is very high and the operating cost very small, the propulsive power costs roughly the same whether the reactor is running or is idle. That means that you cannot afford to have an atomic-powered ship lying around in port for a long period. It would not pay to install reactors in ships unless they are running nearly continuously and at a high rate of speed. In the case of an ordinary ship there is a theoretical limit to its speed. If a cargo ship has a speed of twenty knots, it will consume 6 per cent more fuel to increase its speed by 1 per cent. If it must carry so much more fuel, it must be built larger, and then it will need even more fuel to push it through the water at a given speed. So you have a vicious circle, and it really does not pay to increase the speed past a certain point. The use of atomic energy, however, gets around this difficulty. The construction of the hull offers a problem, but that can be solved.

At the international conference on peaceful uses of atomic energy one question that is certain to arise is this: Where on the earth is atomic energy most likely to be used, and where will it pay to go ahead? Many persons would probably say: in those areas where there is a shortage of electricity. But let us look at the figures on the supply of electricity in different countries. Norway, which is the highest consumer of electricity per head in the world, has 1.2 kilowatts per head installed. The United States, which comes next, has about half as much—0.6 of a kilowatt per head. The United Kingdom, Denmark, and Australia have roughly the same—0.4, 0.3, and 0.4, respectively. Thus the standard of living that prevails in these countries today seems to require about 0.5 of a kilowatt per head. Otherwise, it would be a coincidence that countries as far away from each other and as different as Australia, Denmark, the United States, and the United Kingdom have roughly the same amount. If it seems anomalous that Norway should have twice as much per head as the United States, the reason is that Norway has practically no power except hydroelectric power, and therefore uses electricity for lots of things—heating houses, for example—for which oil is used in this country. In Japan the figure is about 0.13, in India 0.01.

It is not at all certain, however, that we should rush to the countries of lowest electricity production and start building atomic-energy plants there. Surprisingly enough, some of those countries believe they have surplus power for the moment, their development being too low to need a larger amount. They use power only for small machines.

The Pattern of Use

The point I want to make is that the matter is not so simple as it may seem. If we are going to double the use of electricity in any country, we must also double its national income. That is why I personally think that atomic energy will first be used in countries which already have fairly high power production and would like to increase it. Ultimately, of course, countries with little or no electricity will want larger amounts.

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But for the next ten years it is technically highly developed countries with a lack of power, especially those whose energy resources are running out, which will be most in need of atomic power. A long-term program, for twenty-five years or more, would include countries in which technical development must be accelerated.

Certain places might prove exceptions to this rule. There might be a desert area where 500,000 kilowatts could be used for irrigation. The standard of living of the inhabitants would thus be raised while they continued to do the work they were accustomed to. An outside state would probably have to build the reactor and send in people to run it.

Even the smaller European countries have their atomic-energy commissions and their plans for development in this field. Their aim at present is to develop the technological background which they need in order to utilize atomic energy. If they find out later that they are able to build their own power reactors, they may want to do so. It is not likely, however, that many small countries will consider it practical to start a complete power-reactor industry. They will probably content themselves with producing specialized equipment and parts for atomic-power plants. The electronics industry in Europe can compete in both size and quality with any in the world. The small powers also have their metallurgical industries, which would be able to take up the production of special metals. European industry has lately shown an increasing interest in getting a foothold in the government-sponsored atomic-energy programs. It is possible that competition from firms in the smaller European countries may in time reduce the market for the big firms of the larger countries, but if any industrial application of atomic power is undertaken in Europe within the next five or ten years, it will be done by employing the technological and production capacities of the larger countries.

Atomic-energy installations in the underdeveloped areas of the earth will have to be part of some long-term plan for the whole economy of the region. Such a plan would doubtless include the setting up of industries which would be interested not only in using atomic energy but in taking part in its production. Their progress, however, would hardly be fast enough to enable them to compete with the older atomic industries in other parts of the world.

The importance of starting at a highly industrialized level makes it probable that atomic-energy production as an industry will become of economic importance in the United States as early as in any other country, in spite of the general belief that its development will be held back by the abundance and low price of available energy here.

PATTERN FOR AMERICA

by Walter Isard and Vincent Whitney

ATOMIC development is by now a thoroughgoing commitment of the principal industrialized nations of the world. While many details of this current program of nuclear research and development are obscured by considerations of secrecy, the continuing activity and the mounting progress are clear enough. Any conscientious reader of the reports of the Atomic Energy Commission and of the hearings of the Joint Committee on Atomic Energy of the United States Congress can follow their general outline. Appropriation requests to the Congress furnish another clue. And the daily press, though sometimes excitable or visionary, mirrors the cumulative atomic ferment.

One of the most significant changes in the nuclear activities of the United States government during the past year has been the emergence of a limited but real emphasis upon atoms for peace. This new and important emphasis derives in part from the growing awareness of the Administration in Washington that atomic development can be made a potent political weapon in international affairs. Hunger, disease, poverty, and oppression are widespread in the world today. Peaceful uses of nuclear energy suggest a dramatic approach to an attack on these conditions, which, so long as they exist, remain a threat to economic and political stability. The compelling appeal of such a use of nuclear energy may have led to over-optimistic expectations. But what is important is that the United States has at last begun to allocate some share of its funds and interest to research designed to employ nuclear energy for constructive purposes. The consequences will inevitably be meaningful for our own economy regardless of their effect upon international relations.

Until the last year the government of the United States had not demonstrated any effective interest in atoms for peace. The principal exception had been the production and distribution of radioisotopes for medical, industrial, agricultural, and other scientific purposes. It is also true that by-product power in inconsequential amounts was derived from various nuclear-energy installations such as those at Arco, Idaho, and at the Argonne National Laboratory outside Chicago. And atomic power in amounts ranging up

WALTER ISARD, associate professor of regional economics at the Massachusetts Institute of Technology, and VINCENT WHITNEY, chairman of the Department of Sociology of Brown University, are the co-authors of "Atomic Power: An Economic and Social Analysis."

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to 10,000 kilowatts has now been offered for sale, beginning July, 1955, at the West Milton, New York, facility, where such power is produced as an incidental function of the operation of a research reactor. It should also be pointed out that at the level of basic research, findings can of course be applied to peacetime as well as to military purposes.

The A. E. C.'s Five-Year Plan

A strong stimulus to new peacetime applications is the five-year program of reactor development which the Atomic Energy Commission is currently pushing. This again has grown in part out of the military need for mobile reactors, but it is serving simultaneously to test the suitability of five basic nuclear systems for power production. By late last fall sixty-five companies were investing private funds in atomic-power research and development. The Dow Chemical-Detroit Edison and Associates group reported expenditures and commitments for atomic research and development in 1954 totaling $1,900,000. The Duquesne Light Company of Pittsburgh is under contract with the Atomic Energy Commission to build and operate a new turbo-generator plant at Shippingport, Pennsylvania, twenty-five miles from Pittsburgh on the Ohio River. When completed, the company will operate the reactor portion of the plant. Up to $5,000,000 of the development and construction costs for the reactor portion of the facility are being borne by Duquesne, although the government has allowed a 75 per cent tax write-off on the company's investment. This is an experimental but commercially usable atomic-power plant based on a pressurized water reactor. It is intended to furnish a minimum of 100,000 kilowatts of electricity to Pittsburgh by 1957.

These illustrations are cited to indicate the kind and extent of involvement of private industry in the atomic-energy program which is resulting from changes made in the Atomic Energy Act of 1954. Yet sizable as such private investments are in themselves, they remain small in comparison with the outlays of the federal government. Alfonso Tammaro, assistant general manager for research and development of the Atomic Energy Commission, referred last July to federal expenditures of several hundred million dollars in the next five years and of nearly a billion dollars more for prototype plants and pilot models in the next decade. The development of atomic power both in the United States and abroad has so far depended overwhelmingly on government subsidy, both direct and indirect. This is not likely to change in the next decade.

The economic justification for such a prediction can be found in the staggering cost of the essential continuing research and of the experimental operation of nuclear reactors. These factors are reinforced by the unfavorable cost position of power based on nuclear fuels compared to that based on such conventional fuels as coal and oil. In what period of time and under what conditions atomic power can be made competitive is a matter of argument which can only be resolved ultimately by actual operating experience with nuclear stations. There is general agreement that under present conditions unsubsidized atomic power is not competitive. The majority of current studies—and these are largely dependent on calculations made on paper—agree that an atomic-power plant will require a greater investment of capital than a steam station of comparable output based on coal or oil at present prices. A nuclear station must have a turbine-generator similar to that of a conventional steam station and, in addition, a reactor or a combination of reactor and heat exchanger. Special chemical and metallurgical facilities may also be needed. These require a total investment considerably greater than for the usual boiler in which coal or oil is burned. Even if the successful development of the experimental boiling-water reactor ultimately eliminates the necessity for a heat exchanger, the requisite capital investment is still expected to be greater.

General Electric Estimate

Francis K. McCune, general manager of the Atomic Products Division of the General Electric Company, has given one of the most optimistic estimates of such investment cost. Addressing the Atomic Industrial Forum in 1954, Mr. McCune presented data for a nuclear plant of 300,000 kilowatt capacity utilizing a light-water-moderated boiling reactor. He estimated that an investment of $243 will be required for each kilowatt of output. This figure includes the nuclear-fuel inventory. The investment for a coal station of comparable capacity would amount to $160 per kilowatt. Reckoning all costs the power from the nuclear station, operating at a plant-utilization factor of 80 per cent, would cost an estimated 6.7 mills a kilowatt hour as compared with a kilowatt-hour cost of 6.9 mills for the comparable coal station.

A second estimate presented by Mr. McCune is for a graphite-moderated, water-cooled reactor. This would have a capacity of 700,000 kilowatts, which is unusually large, and would operate at a plant-utili-

FUEL PRICES AT A RANDOM SAMPLE OF CENTRAL STEAM STATIONS IN THE UNITED STATES, 1945

State	Number of stations	Price of fuel in cents per million B. t. u.*	
		Range	Median
LOW COST			
Arkansas	2	3-9	6
Texas	16	4-24	8
Louisiana	4	6-15	9
Oklahoma	1	-----	9
Kansas	8	10-15	12
Kentucky	4	10-17	12
HIGHEST COST			
Rhode Island	1	-----	26
Connecticut	4	24-34	28
Florida	5	26-31	28
Massachusetts	14	24-33	28
New Hampshire	2	28-31	30
Vermont	1	-----	41

Source: Estimated from reports drawn in a random sample from the files of the Federal Power Commission by John B. Lansing. For complete table see Isard and Whitney "Atomic Power," New York, (The Blakiston Company, 1952), p. 42.

*British Thermal Units, the standard measurement of heat.

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zation factor of 85 per cent, which is high. Very favorable assumptions are also necessary about the cost of fuel, reprocessing, and depreciation and about interest rates on the capital utilized. If all these factors are allowed, the per kilowatt-hour cost of atomic electricity is a competitive 6.8 mills.

These figures are cited because they represent the most optimistic specific estimates of the cost of atomic power to come from a responsible spokesman for a large American industry actively connected with the atomic-development program. The large size of plant and the high plant-utilization factor may be realistic for a limited number of nuclear-based stations in heavily industrialized regions such as the American deep-water rim or the Midlands of England. Such stations would presumably be integral parts of major electric systems or groups of systems with extensive and relatively far-flung distribution facilities.

Numerically, such "giants" constitute only a small fraction of the American electric plants, although they produce a substantial proportion of the electric power used in the United States. The most recent published American data show 450 privately owned electric companies, about 2,300 electric systems owned by municipalities and other public bodies, and approximately 1,000 rural electric cooperatives either producing or distributing electric energy or doing both. Testifying before the Joint Committee on Atomic Energy of the Eighty-fourth Congress in February, 1955, Alex Radin, general manager of the American Public Power Association, reported that only about 1 per cent of the nation's electric utilities—39 out of over 3,750—would be eligible to participate in the current power-reactor demonstration program of the Atomic Energy Commission. Mr. Radin's testimony reflects indirectly the limited capacity of the great majority of the publicly owned systems, including the rural electric cooperatives. Only a few of these are large enough to suggest the use of even 200,000- to 300,000-kilowatt generators in the foreseeable future. For the majority, at their present size, reactors with capacities of from 5,000 to 30,000 kilowatts are most appropriate.

"Proletariazation" of Power

The advantage of this process [the use of breeder reactors], as regards the underdeveloped areas of the world, are incalculable. The 600 tons of uranium which I previously envisaged would correspond to a doubling of today's consumption of fuel, equivalent to the consumption of 5,000 million tons of coal. With an extraction rate of 1 per cent of metal, the 600 tons of uranium would require 60,000 tons of ore, which is a tonnage 80,000 times less than that of the coal that would be required to produce the same energy.

The transition from the thermal era to the atomic era would thus take the form of a reduction, by a ratio of 80,000 to 1, of the weight of the materials or ores to be extracted, and a reduction of 100 times larger would make the ratio 8 million to 1 in the weight of the fuel to be transported from the mine to the furnace. Atomic power thus appears to be easily dispersable and transferable into regions lacking in other rsources.

This sort of dissemination doubtless would spell immense social progress in making available large power resources to all peoples. In the same manner, the portable reactors now being built in America —which are known by the striking and expressive name of "power package"—constitute a happy augury for the international proletariazation, if I may so call it, of power to be placed at the disposal of mankind.

Jules Mook, French representative on the U. N. Disarmanent Commission, before the Political Committee on November 8, 1954.

These statements, of course, imply a static condition. They are based on the assumption that the development of relatively cheap atomic power from reactors of large capacity would not alter the operating and ownership structure of American utility companies. Such an assumption is hardly consistent with past trends in American economy and society. On both historical and logical grounds it seems probable that major changes in the structure of the utility services in the direction of increased concentration would *follow* any demonstration that atomic power can be cheap power only when produced on a large scale. The fact that atomic-energy study teams have been organized by both private- and public-utility groups suggests the probable ultimate necessity for higher concentration of both management and operations.

Small Stations Suffer

Mr. McCune's estimates of atomic electricity at a cost slightly below 7 mills a kilowatt hour are not applicable to the stations of small capacity referred to by Mr. Radin. Neither are they likely to prove realistic for economically underdeveloped regions. In both instances limited capital and limited markets for power are restricting factors which will tend to prevent the achievement of the assumptions underlying Mr. McCune's estimates.

An initial investment of $73,000,000 is required for a boiling reactor and one of $194,000,000 for a graphite reactor of the size posited. Such amounts are far from negligible in themselves. Particularly in underdeveloped regions capital for nuclear facilities would have to compete with the host of other needs for capital investment—for transportation, for basic industry, for education and welfare services, and so on. And since interest rates in underdeveloped regions are inevitably well in excess of those paid in the United States, such areas will labor under an additional serious disadvantage. For an assumed situation similar to that presented by Mr. McCune, a difference of 3 per cent in the interest rate on borrowed capital between regions can result in a cost increase of 2.5 mills for each kilowatt hour of electricity.

Even if the necessary capital can be made available, it will make no economic sense to build a nuclear plant with a capacity of 700,000 kilowatts, or for that matter, of 300,000 kilowatts, unless there is a market for its output. Among other things, this implies the necessity of a substantial supply of power-using equipment and facilities. These in turn require a sizable investment in power-operated industrial and household equipment. Outside the major industrial nations there are few areas where such equipment exists

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in amounts adequate to furnish economic justification for the construction and operation of nuclear reactors of large capacity.

In such regions, as well as in areas of the United States served by small electric plants, reactors of 5,000 to 50,000 kilowatts capacity are more rational. But the price the consumer would pay for power from such stations would be relatively high because large investment costs would have to be allocated to the relatively few kilowatt hours produced. Moreover, a plant-utilization factor of 80 per cent or more is rarely achieved, especially where part of the power is for household consumption. The irregularity of household periods of demand means that peak capacity must exceed average kilowatt-hour use. If for Mr. McCune's higher figure we substitute a plant factor of 50 per cent, the typical operating level for steam stations in the United States, his estimated kilowatt-hour costs are raised from 6.7 mills and 6.8 mills to about 11 and 12 mills. Reducing the high capacity assumed would raise costs further.

This is clearly shown for existing stations in the United States. According to figures for 1950 compiled by the Federal Power Commission, generating costs for electric utilities with gross annual electric revenues between $25,000 and $250,000 a year approximated 11.2 mills for each kilowatt hour. In the same year utilities with gross annual electric revenues in excess of $250,000 a year showed a comparable cost of approximately 4 mills per kilowatt hour produced. The great majority of the publicly owned systems fall in the first group. Their average installed capacity was only 19,500 kilowatts as compared with an average of 223,450 kilowatts for the larger utilities, which are mainly privately owned systems. Similarly, net plant investment averaged $7,675,000 for the first group and $71,957,000 for the second.

If nuclear power is to be cheap power, apparently it must come in big blocks. As Norbert Weiner of the Massachusetts Institute of Technology told *The Nation's* Conference on Atomic Energy in 1950, "It must be production on a large scale indeed to be able to amortize the enormous preliminary expenses." It is understandable why Mr. McCune talks in terms of reactors with a capacity of 700,000 kilowatts, which, as we have indicated, is an unusually large output even for plants in industralized countries.

Extensive use of atomic power in the next quarter of a century is dependent then upon one or both of two factors. The first is extensive subsidization by a nation or by an international authority. The second is finding ways to make atomic power really economically competitive with existing sources. Actually, a combination of these two approaches can be expected.

The Need for Subsidies

It seems inevitable that subsidization will play a major role in the present experimental and developmental period. Appearing before the Joint Committee on Atomic Energy in February, 1955, one of the leading advocates of private enterprise in the atomic-energy program, Walker L. Cisler, president of the Detroit Edison Company, testified:

> . . . the work carried out by the [Atomic Energy] Commission as a part of its regular program was very helpful to us. Certainly we could not have reached the point that we have without the benefit of that.
>
> My understanding was that the commission would help in any actual research work but not in any actual building of a facility where that facility was going to be owned privately.

A little later in the same hearing Representative Holifield of California concluded a question by stating: "But in addition to the work you are doing, the A. E. C.'s five-year program is really doing the major part of the research and development work in the field at the present time." Mr. Cisler replied: "I believe that is true." It is hardly conceivable that any private company or group of companies could expend funds on the scale necessary to initiate and carry through the basic research and development which are essential to any ultimate widespread use of atomic power.

With or without subsidization the cost of atomic power remains a matter of conjecture. We have no operating experience with a nuclear station designed to produce atomic power in constant, commercially usable quantities. Furthermore, we cannot be sure in what ways subsidization will be employed, directly or indirectly, to lower the cost of such power to the producer and to

Sooner Than We Think

Atomic fuel offers the only chance to meet the soaring demand for electric power while reducing its cost. This is the message utility heads have been bringing to stockholders in recent months. Although initial costs of building atomic-powered plants run as much as $90 a kilowatt higher than conventional steam plants, the two types are expected to meet on equal competitive footing as early as 1962. H. R. Searing, president of Consolidated Edison Co. Inc., told shareholders at the annual meeting last week that reductions in the cost of producing electricity could come about "only with atomic power." He offered two major points to support this argument:

1. Modern technology has just about squeezed the maximum efficiency from conventional fuels. A pound of coal cannot be made to produce much more heat for the production of electricity.

2. Costs of coal, oil, and gas will rise as resources are exhausted and as the country's demand for electric power expands to meet increased industrial production. Power requirements are expected to more than double by 1970 so. even with more efficiency, savings in power generation will not keep pace with spiraling fuel costs.

Mr. Searing pointed out that this reduction in the cost of nuclear fuel has been achieved to the point where Consolidated's proposed plant at Indian Point, Buchanan, New York, will turn out electricity at a cost of 0.9 cent a kilowatt hour. This figure compares with a cost of 0.75 cent for a kilowatt hour of electricity from the company's newest conventional plant in Astoria. . . .

New York Herald Tribune, May 21, 1955.

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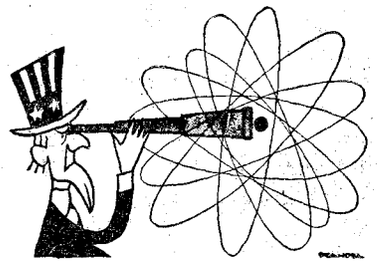
the consumer. Other variables are increasing demand and possible changes in the cost of competing fuel sources as these become less plentiful or more costly to produce under conditions of decreasing accessibility. Informed guesses, based on present annual rates of consumption, call for the exhaustion of the coal reserves of the United States in a thousand years. It is possible that America's oil fields will be depleted in a few decades, although much depends on whether important ground pools will continue to be discovered. If the progressive exhaustion of sources of fossil fuels becomes pressing, this will necessarily improve the competitive position of nuclear fuels. There is every indication that increasing demands for electric power in the next two decades, in the United States and elsewhere, will require substantial additional amounts of solid fuels. Such rising demand will create a condition in which nuclear fuels can more readily supplement existing solid fuels than would be the case if power requirements were finite. Existing installations and the tremendous investment they represent need not be scrapped. Coexistence of conventional and nuclear stations can be expected. Under such conditions a climate favorable to atomic development is created.

The emphasis on relative cost suggests that atomic-power stations are likely to appear first in regions of the United States where existing power costs are relatively high. The table on page 543 shows the fuel prices at steam stations in the United States in 1945 for the six highest and lowest-cost states from a random sample of forty states. The six lowest-cost states are all part of or immediately adjacent to areas of oil and gas production. Their median fuel costs range from 6 to 12 cents per million b. t. u. (British thermal units, the standard measurement of heat). The six highest-cost states, with median fuel costs above 25 cents, consist of Florida and five of the six New England states—Maine was not in the sample. These are areas which produce no fuel and which are at a distance from the principal centers of fuel production. The situation is similar in Puerto Rico to the extent that power costs are also high.

Both because of these high costs and because the higher revenues which would likely result would lower correspondingly the amount of government subsidy needed by an atomic station, it would seem at first glance that the earliest plants would be located in areas like New England or Puerto Rico. Actually, much more detailed economic analysis is needed to test the plausibility of such an assumption. Has the area accessible low-cost hydro sites which are not in use? Can the area absorb the output of an additional power plant, especially if the charges for power are not decreased? It is entirely possible that an area where the current cost of power is lower may still be in a better position to absorb an increased amount of power without a reduction in price. Is the demand for power increasing at a rapid enough rate—as it is in



Puerto Rico? If the demand is relatively stationary, would the introduction of an atomic-power plant which produced power to be sold at less than the going rate induce industrial development which would ultimately absorb the increased power? Under such conditions the introduction of a subsidized plant in such a region might be justified as a means of combating unemployment and lowering welfare costs and services. New Englanders might also contend that building a plant in that area would serve to correct in part the existent imbalance between the federal collection of moneys there and federal expenditures. The point is that the location of atomic stations, in the near future at least, is likely to involve many issues other than those of simple economic cost. Such policy decisions cannot be avoided. Nor can they safely be predicted in advance.

Perhaps a more concrete approach to the problem of developing economically competitive power lies in the continuing attempt to find methods of reducing costs through technological improvements. One important current development which could prove of merit in making atomic electricity available at competitive prices, especially in industrialized areas, is the multiple-purpose reactor. Its special distinction is its possible ability to produce several products or to perform several functions simultaneously. The manufacture and sale of plutonium, presumably to the federal government, could be a cost-reducing item allied with the production of power. It is even conceivable that a single reactor could produce power, radioisotopes for industrial and scientific purposes, and perhaps both new chemical products and considerable radiation for industrial use. Or a reactor designed primarily to produce power might also be used for land-development projects such as irrigation or the desalting of brackish water. Unit costs would then be reduced, perhaps substantially, by spreading the high fixed costs on the large initial investment over many units of output. Several large chemical companies in the United States, including Dow and Monsanto, have already spent considerable amounts of money in exploring the area of new chemical processes and products related to nuclear development. Important findings seem likely to emerge from such explorations.

A New Industry: Irradiation

Actually, the development of entirely new products and processes made possible by the application of radiation energy may well represent one of the ways in which nuclear research will have a profound impact on the economy. The effects of radiation have been observed by biologists and chemists for several decades. Studies have been carried on based on such radiation sources as radium preparations which have natural properties of radiation, X-ray machines, and, more recently, particle accelerators. Nuclear research has understandably intensified radiation studies and, specifically, has stepped up the available supplies and intensity of radiation and opened largely unexplored areas of industrial processing in many fields.

In the latter field some persons expect radiation applications to produce really revolutionary changes.

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"Some day that'll all be done by atomic power"

For instance, it is reported that soft plastic sheets can be changed into sheets of the same thickness stronger than structural steel and so highly resistant to heat that the need for fireproofing in building construction is eliminated. The change is attributed to massive doses of gamma radiation. Much more certain is the report that irradiated polyethylene pipe will have an enormous advantage over ordinary polyethylene pipe in that it can be used not only for cold-water but also for hot-water systems. Irradiation obviously increases the potentialities of plastic as a substitute for copper and metals in a wide variety of household and industrial uses. Irradiated materials may prove serviceable for structural purposes and help to alleviate part of the critical shortage of building materials in some countries. Such plastics could stimulate a whole economy in a region which is a suitable location for manufacturing plants.

Late in January the Atomic Energy Commission announced that gamma-ray irradiation had been successfully employed in vulcanizing rubber. Exciting possibilities for the use of radiation also lie in the sterilization of pharmaceutical and surgical products. As we steadily increase our knowledge of the way in which radiation acts on flavor and odor, it is increasingly probable that it may be used in preserving foods for indefinite periods.

By leading to new products and new processes of this sort irradiation may speed the actual erection of multiple-purpose reactors and improve the chances of getting atomic power down to cost levels that are attractive to power users. It may also produce cost savings in quite a different way. If the spent reactor wastes, which now create a serious disposal problem, can be used for irradiation purposes, as has been suggested, part of the money now charged to disposal can be saved. More than that, the wastes, now a nuisance and a hazard, can be made to yield revenues if they are sold to industry for radiation jobs. As an alternative, an irradiation plant might be located near a nuclear station. Various products would be shipped to the plant to be irradiated. The price which industry could pay for such service might well exceed the cost of operating the irradiation plant—and also of processing the wastes if this were necessary to make them effective for particular radiation purposes. The cost of atomic power could thus be reduced.

Admittedly, the economic feasibility of such irradiation uses is still highly speculative. Particle accelerators—popularly called "atom smashers"—can already produce radiation at lower cost than that expected from reactor wastes or from nuclear energy directly. Furthermore, a relatively large number of reactors will be needed to meet the radiation demand for any large industrial process. Much may depend on whether, for various political and military reasons, government funds are used to subsidize the radiation phase of nuclear development. If they are not, nuclear-based radiation processes will have to meet stiff competition from the use of less costly particle accelerators.

Effect on Urbanization

A less hazardous area of prediction is found in the consequences of nuclear development on industrial location and population aggregation. Our assumption is that atomic power will become an important supplementary source of power in the United States in the next few decades. We also assume that competitive cost levels will finally be achieved.

At first glance it might appear that cheap, ubiquitous atomic power would result in a radical shift in the distribution of both industry and population. Actually, such a possibility is remote and probably nonexistent. Few major industrial groupings are so dependent on power, to the exclusion of other lo-

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cation factors such as nearness to market, adequate labor supply, good transportation, and so on, that a new power source will in itself suggest plant relocation or even the development of a new location for additional plants. In very few American industries do the kilowatt hours of electric energy consumed per dollar value of product exceed ten. And for all industries combined, at no time in the past fifty years has the ratio of fuel and purchased energy to value added by manufacture exceeded 7 per cent, the 1909 figure. Actually the ratio had fallen to 4.5 per cent by 1947.

Industries such as tobacco, leather, and various steel-fabricating activities are minor power users. Atomic power will have no important direct effect on their location. Some industries which are fairly large consumers of power find other factors determining so far as location goes. Pulp and paper mills, for instance, will seek sites near the source of their raw material in order to reduce weight and bulk and keep shipping costs reasonable. Atomic power will not change their situation. Nor will cement plants be induced to move from areas close to both markets and raw materials, where their transport costs are minimized.

Studies which we have presented in detail elsewhere suggest that even in the power-conscious electro-process industries, such as aluminum production, both existing and future capacity is likely to remain at or to seek new cheap hydro-electric power sites so long as these are available. Even if atomic power could be sold at 4 mills a kilowatt hour, a highly optimistic figure, the aluminum industry would still find it more economical to retain its present split location pattern in order to make use of hydro power at 2 to 2.5 mills a kilowatt hour.

Industrial Sites Have Edge

There is no indication that any extensive decentralization of industry is likely to occur as a result of the use of atomic power. Nor are there any new industrial processes made possible by nuclear applications which might alter this conclusion. While military or political decisions could conceivably lead to some uneconomic industrial concentrations in remote areas such as the Rocky Mountain states, it is far more likely that a continuation of existing trends will tend to perpetuate present concentrations of industry. Because they are the principal areas of demand for power in this country, the industrial areas of the Northeast and along the Great Lakes rim are also the most appropriate sites for atomic plants from an economic viewpoint. Atomic power could stimulate the industrial expansion of such an area as Southern California if it became competitive in cost with existing power sources. But on balance it does not seem likely to disturb current concentrations of industry and population in the areas of present greatest density. Major metropolitan districts are likely to continue their expansion, presumably with a further spur to the diffusion of plants and population within their borders.

Many technical problems remain. In fact, we have only begun to work on many of them. In their solution may be found an answer to the basic economic question: How can atomic power be made competitive in cost with existing fuel sources? It is a matter of faith—but probably one which is justified—that ultimately ways will be found. We can then expect that atomic power will prove a useful adjunct to other sources of energy. There is no evidence that it will work miracles and radically reshape our economy or society.

But we shall have to wait a while longer to discover the new products and processes which will undoubtedly evolve from today's research. We shall have to wait to find out whether the cost of atomic power can be kept low through the use of reactors with joint products and functions. We shall ultimately know too whether steam can be produced directly in a nuclear reactor to drive electricity-producing turbines without contamination danger. We shall discover whether "package" reactors, portable units, can be dynamic factors in stimulating economic activity in remote and undeveloped locations.

The future of the atom seems assured. But perhaps there is a parallel with our children. We have no lack of confidence in their success, but we are not wholly sure what they will turn out to be when they reach maturity.

The Promise Of Plastics Strong As Steel

Perhaps the most dramatic of the radiation developments is the manner in which it can affect the process of molecular polymerization—taking simple chemical building blocks and forming them into strong and elastic materials. There are indications that common plastics can be formed into desired shapes and subjected to radiation that rearrages the molecules and produces a new substance as strong as steel The promise of lightweight, fire-resistant steel-strong plastics nas led some members of the construction industry to a seemingly fantastic view of the industry's future. The tons of fireproofing that represents four-fifths of the weight of the average building could be dispensed with, as could the even higher proportion of time, labor, and investment. Floors would weigh only a fraction of what they weigh today, as would the columns and partitions that carry them. Visions of vastly larger spans, building material that will support itself and insulate itself, simple structural materials that can be transported by air and locked together on the site—all these and more are the accomplishments that irradiated plastics may be expected to produce. Much remains to be done, of course—years of trial and error will be necessary to find the materials that are capable of transmutation into new and useful forms. But it has been demonstrated that gamma radiation can alter the molecular structure of many different materials, to give them greater strength, greater elasticity, and greater heat resistance. This is potentially the greatest and most promising field for the development of atomic energy.

Eugene M. Zuckert, former United States Atomic Energy Commissioner.

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V. THE PROBLEM OF CONTROLS

So long as fissionable materials can be used for either peace or war, their control by some governmental or supra-governmental authority is obviously needed. In this section James G. Beckerly poses the question: Has the United States hindered progress by an excess of "know-how" controls? But there is another aspect to the problem: Who will control the atoms-for-peace industry in the United States and for whose benefit? Leland Olds discusses this vital issue in terms of practical politics.

THE URANIUM CURTAIN

Dangers in Secrecy . . *by James G. Beckerly*

AN ACT OF CONGRESS in 1946 gave unprecedented authority to a commission to control all phases of atomic work, including that fragile but essential item, information. A new law was passed last year reducing some of the abnormalities. But the congenital defect remains—information on the peaceful uses of atomic energy is still controlled along with purely weapons data. The peaceable atom is free to go out of doors but it is still in purdah.

In retrospect, the tendency to excessive secrecy is understandable. Many men of good intent subconsciously or consciously felt the knowledge of how to make fissionable material, key ingredient of bombs and fuel for nuclear-power plants, was an awful secret to be kept within a select circle. On one occasion several years ago I recall a Nobel laureate in deadly earnest suggesting the formation of just such a privileged group among American physicists. The secrets of the atom were not to be intrusted to fallible men.

The Baruch Plan contained variations on this theme. An international elite body was to possess all the know-how and experience in the manufacture and use of fissionable material. The operators of the international trust would be drawn from the best and most reliable scientific talents of all nations. Congress in 1946 reflected the prevailing spirit. It could hold secret "all data concerning" the manufacture of nuclear fuels and their use in the development of power, in addition to those data concerning the manufacture and use of atomic weapons.

So the "uranium curtain" was created. Essentially, all public knowledge of the atom was sandwiched between the covers of the Smyth report. All atomic information was controlled. Only a select few could work on the many and difficult tasks required to harness the atom for peaceful power. But no one wanted to work on nuclear power without full knowledge of the "prior art." In fact, there was even a question whether such work could be permitted under the Atomic Energy Act. The censorship authority of the act was never an issue in any court action, so that the reality of the uranium curtain was never probed.

The Turning Point

Two events altered the whole outlook on atomic secrecy—the detonation of an atomic bomb by the Russians in September, 1949, and the jailing of Klaus Fuchs in January, 1950. I remember the first with some vividness since it occurred only a few weeks after I had come to Washington to take up the newly created job of "Director of Classification," the job of implementing and interpreting the A. E. C.'s secrecy policies on technical matters. It was obvious that the whole existing philosophy of atomic secrecy had to be scrapped.

Fuchs's effect on atomic security was complex. Some argued that the Fuchs espionage proved that the U. S. S. R. depended on stolen data and that information and people should be controlled even more stringently. Others argued that while Fuchs's data may have helped the U. S. S. R. in narrowing the scope of its technical program, still the fact that it had made fissionable material and tested it in a nuclear explosion showed very substantial capability. More than that, the timetable of the Soviet program showed a considerable determination backed up by great investments of men and materials. It seemed clear that if, for example, the Soviet atomic group wanted to know about the design, manufacture, and performance of explosive lenses for detonating A-bombs, they would not wait for a Greenglass to send over sketches. They would find out for themselves.

I recall days and weeks of wrestling with the implications of the Fuchs case, studying all the data obtainable, discussing all aspects with many experts. The consensus was that the Fuchs case did not indicate a need for increased secrecy; if anything, it indicated the opposite.

Thus in 1950 information on the peaceful atom began to emerge. Although before then much valuable basic-research information had been released, no complete body of data on nuclear reactors, the basic devices for atomic-power generation, had been published. Beginning late in 1950 accurate and complete information on nuclear reactors was issued. Initially it was a slow process, but within a few years there were tangible results—public tours of reactor

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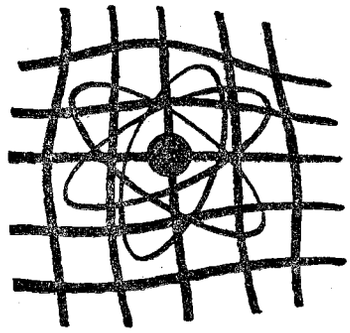
facilities, textbooks on the basic technology, an open-to-the-public reactor in one university, many others on the drawing boards.

The gradual emergence of information on the peaceable atom from the confining quarters of guarded classified filing cabinets was slowed somewhat by the appointment of a new chairman to the commission. His arbitrary refusal—on security grounds—to release in August, 1953, an innocuous status report on nuclear reactors was somewhat of a shock to many of us on the A. E. C. staff. The effect of this decision, plus many others of a similar but less significant nature, was to generate a definite anti-information attitude in the commission staff. In the atomic-power field this attitude seems now to have been dissipated; at least this is the implication of the preparations for next August's conference in Geneva.

The Atomic Energy Act of 1954 continues the information-control provisions of the original act. However, it embodies some significant changes in "attitude," if that term can be applied to legislation. In place of the strong language of the 1946 statute, under which the commission had to determine that publication of information would not "adversely effect the common defense and security," the act of 1954 refers to a determination that publication will not entail "undue risk" to the common defense and security. This is a real change.

Perils of Secrecy

But it is not enough. Information control by the executive branch of the federal government in a free society is a dangerous practice and should be limited to just these activities of overriding significance to our military defense. Why should the government conceal information on nuclear-power plants for production of electricity to supply our cities and countryside? Why should the A. E. C. conceal almost all the technical data developed by duPont in producing, at taxpayers' expense, heavy water? Why should the A. E. C. conceal all the know-how and experience gained by Westinghouse in building and operating pressurized-water power-reactor systems? What about General Electric's considerable information on producing the nuclear



fuel, plutonium? (This is not a criticism of duPont, Westinghouse, or General Electric, for the situation is not of their making but stems from the Atomic Energy Act.)

The present Atomic Energy Act should be amended to limit control of information to data on atomic weapons and other purely military matters. There is no need to continue to control information on the production of nuclear fuels or on the use of these fuels in the production of power. Nothing is gained. Much is lost. Domestic industrial efforts are handicapped; monopolistic arrangements are encouraged; our future scientists and engineers grow up without complete data in their texts; we lose good-will in our relations with other free nations.

Perhaps worst of all, however, is the subversion of democratic institutions by unchecked information control. Small groups, appointed not elected, possess tremendous power with only tenuous public responsibility and no mechanism for review. The A. E. C. under present law can define, within very broad limits, just what it has a right to withhold from public view. Realistically, only the Joint Committee on Atomic Energy of the Congress has continuing access to the Atomic Energy Commission's activities—and the present chairman of the A. E. C. has been criticized by the Joint Committee for restricting that access. This group of elected Representatives is essentially the only body which can assure that information control, as permitted under the Atomic Energy Act, is practiced with wisdom and statesmanship. Considering that each individual member of the committee has many other Congressional duties, this means that the Atomic Energy Commission is not exposed to continuous and detailed critical scrutiny. Perhaps this is why it was possible for the A. E. C. to withhold from the American public for more than ten months information on the hazards from thermonuclear bomb fall-out, information essential to adequate civil-defense planning. Information control protects an agency from kibitzing and criticism but may jeopardize our existence as a nation.

In concluding I should like to cite as specific examples two issues which are being acted on by the A. E. C. without benefit of public discussion. Both have long-range national and international significance and should not, in my opinion, be decided in closed meetings by unidentified individuals, subject to little if any independent scrutiny.

"Hidden" Policies

The first is whether information on peace-time uses of atomic energy should be classified so that the information may be used in international bargaining. For example, at public expense this country has learned much about the technology of manufacturing nuclear fuels. Should that information be published or should it be withheld from publication and offered to some other country in exchange for materials or services from that country? Here is a basic problem. It appears doubtful to me that the present act permits bargaining with atomic information, but I can see where it could be argued that such quid pro quo arrangements may enhance the national defense and security. Regardless of the legal question, it does appear that some measure of the democratic process is lost when such an issue never even reaches public view. In fact, I doubt whether there has been any public indication by the A. E. C. whether it is or isn't pursuing, or has or hasn't pursued, such a policy in specific instances. There seems to be no doubt, however, that the practice of secrecy in some phases of the atomic-energy programs of other countries—excluding those we have agreements with—is based on "national-interest" rather than "national-security" considerations. The nation without some "secrets" in the bag may have nothing to exchange.

The second issue I should like to cite concerns the peaceful hydrogen atom, that is, useful energy derived

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from the fusion of light elements. Apparently, the A. E. C. has decided that information on the controlled release of fusion energy should be kept classified. There has been no public debate on the issue, no debate in Congress, unless in a closed meeting of the Joint Committee on Atomic Energy. Now if the subject at hand were a new weapon, control of information might be justifiable. But the value of withholding all information on a potential source of nuclear energy is extremely debatable. Concealment of even the fact and circumstances of a decision on concealment is quite unjustified and bypasses basic and essential processes in our form of government. What assurance is there that adequate work is being done by the commission in this field? What is being done to assume a continuing supply of trained men for the project? Many questions can be raised without even assurance that someone, somewhere is considering them and making an adequate effort to answer. Information control in this instance is, I believe, leading into dangerous waters. "Papa knows best" is not in any article of our Constitution.

STRUGGLE FOR POWER

Industry Wins a Battle . . *by Leland Olds*

THE Atomic Energy Act of 1954 was approved by Congress only after what was probably the greatest legislative battle over the power issue in twenty years. A valiant block of progressive Representatives led by Chet Holifield of California proposed and fought for a series of amendments to the Cole-Hickenlooper bill which would have halted the "giveaway" of the people's great new power resource to private monopoly. But they were beaten down by a majority responding to Representative Cole's whip, as he condemned principle after principle of established federal power policy with such slogans as "designed to put the federal government into the business of generating electricity through the use of atomic energy," "totally foreign to the purposes of the bill as presently written," "designed to put the Atomic Energy Commission into the power business," and so on.

In the Senate Wayne Morse of Oregon led the fight for full extension of federal power policy to the atomic field. This fight appeared won when the Senate passed amendments establishing the basis for the people's control of atomic power, but the Republican steam-roller went to work and the bill came out of conference stripped of the most important provisions. Among those struck out by the conference committee was the Johnson-Metcalf proposal for a new Section 45 which would have authorized the Atomic Energy Commission, in cooperation with the established federal power agencies, to develop a program of federally constructed atomic-power plants, with the power marketed in accordance with existing policy governing sale of hydroelectric power—that is, with preference to both public and cooperative electric systems.

The Amendments

In the course of the debate Senator Everett Dirksen (R., Illinois) revealed the motivation of those supporting the Administration bill. Speaking on an amendment which would have done no more than place companies licensed to produce atomic power under the same kind of regulation by the Federal Power Commission as those licensed to develop water power, Senator Dirksen said: "Mr. President, in my humble judgment the amendment that is before us will come as close to socializing the power industry as anything I have seen in all the days I have been here." Senator Hickenlooper had already misrepresented the amendment as extending federal regulation to intra-state electric rates and had asserted: "It is the old fight as to how far the Federal Power Commission shall move into the sovereignty of the states and local regulatory bodies." Federal regulation of licensees for water-power development has been in effect since the enactment of the Water Power Act of 1920, irrespective of whether the company was engaged in interstate transmission or in wholesaling of electricity. But the amendment in question was beaten in the House and watered down in the Senate before passage until it lost meaning.

The effort to prevent a serious breach in federal power policy, however, was not entirely wasted, for a few vital amendments were passed. These provided (1) that the Atomic Energy Commission should have authority to build large atomic-power stations, after further authorization by Congress, to demonstrate their economic feasibility; (2) that public and cooperative electric systems should be given preference in obtaining power from such stations; (3) that federal power agencies, when authorized by Congress, should have the right to obtain A. E. C. licenses for atomic-power stations; and (4) that preference should be given to public and cooperative electric systems applying for atomic-power-development licenses in case of conflicting applications for limited opportunities.

In its initial acts under the new law, however, the Atomic Energy Commission has entirely ignored the possibility of federal construction of large demonstration stations. Instead, it has moved to afford private power companies an easy opportu-

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nity to preempt the field with as little risk of private capital as possible. This was the substance of the commission's request, made public on January 10, 1955, for proposals to undertake federally assisted demonstration projects under Section 31 of the act, which authorizes the commission to arrange with others for research and development. Meanwhile, the commission has completely ignored Section 32, which authorizes and directs it to undertake the same activities through its own facilities.

With the public and private aspects of the atomic-power business not clearly separated, this cooperation between government and industry threatens to become an instrument for strengthening private monopoly. Large sections of public opinion are under the influence of the false propaganda emanating from the twenty-billion-dollar private-power industry, which is fostering acceptance of the myth that federal responsibility for developing a portion of the country's power supply jeopardizes private enterprise in those other broad fields to which it is adapted. As a result, instead of going straight down the road and risking the people's money in the construction of atomic-power plants, while contracting with private chemical and electric-equipment companies for the necessary equipment, the Republican Administration is offering to private-power consortiums anxious to avoid entrance of the government into the atomic-power business almost any kind of partnership arrangement they ask.

The Public's Capital

Under the policy of the Atomic Energy Commission, embodied in its request for offers to undertake demonstration atomic-power projects, the public will apparently furnish most of the risk capital without hope of getting the full benefits of the resulting low-cost power. Ultimately benefits are expected to trickle down to consumers of electricity from a greatly strengthened private-power monopoly dominating the new atomic age. In its call for these proposals the commission set forth the various ways in which it would furnish taxpayers' money to aid the demonstration projects. But there has been no official public announcement of two other channels through which the private consortiums are finding access to public funds.

The first of these ways of subsidizing private atomic-power development came to light when the Duquesne Light Company, partner of the Atomic Energy Commission in the construction of the much-publicized 60,000-kilowatt pressurized-water-reactor power plant at Shippingport was granted a quick-amortization tax certificate covering

75 per cent of its costs. In addition to furnishing this interest-free capital, the Atomic Energy Commission will finance and build the reactor, taking all the risk while the company gets the power. The second channel for subsidy was discovered when Walker L. Cisler, president of the Detroit Edison Company, told the Joint Committee on Atomic Energy that the Michigan Public Service Commission was allowing them to charge investment in this field to operating expenses, which means to the ratepayers.

Since the Joint Committee ended its hearings early in March, it has given no indication of intending to do more this year than set up an eight-man panel to inquire into the impact of peaceful uses of atomic energy "on our way of life, our economy, our industry, our natural resources, and including the effect on employment." The panel is to submit a report not later than January 31, 1956, recommending "any legislative or policy actions needed to speed the proper development under both government and private auspices of peaceful uses of atomic energy." Except for one member, Samuel B. Morris, general manager of the Los Angeles Department of Water and Power, the committee's advisory panel is stacked in favor of the government-private monopoly partnership, with private monopoly dominating. The Democrats have taken over control of Congress since Republican majorities struck from the atomic-energy bill the amendments that would have provided for full extension of federal power policy to this new power resource, but they have sidestepped any move to restore those provisions during the present session.

Four New Bids

The Atomic Energy Commission has announced that in response to its request for proposals to undertake demonstration projects it has received four offers to construct atomic-power plants with a combined capacity of 445,000 kilowatts of capacity at an estimated total cost of about $150,000,000. The four bidders will bear from 80 to 90 per cent of this cost. It is interesting that except for the Consumers' Public Power District of Nebraska, the bidders are private-power consortiums; they are the Nuclear Power group, the Yankee Atomic Electric Company group, and the Atomic Power Development Associates group. Together they represent twenty-six major companies with combined assets at the end of 1953 exceeding $8,000,000,000. Assuming they propose to invest a total of around $100,000,000, the investment of each company will average less than $4,000,000, spread over four or five years. Clearly, this sum can readily be charged to operating expenses, as the Detroit Edison Company, one of the group, has already arranged to do.

Early in May the Nuclear Power group, which includes the American Gas and Electric System, the Commonwealth Edison Company of Chicago, the Pacific Gas and Electric Company, the Union Electric Company of Missouri, the Central Illinois Light Company, and the Illinois Power Company, notified the Atomic Energy Commission that the directors of the member companies had approved the proposal to build a 180,000-kilowatt atomic-power plant forty-seven miles southwest of Chicago and that the General Electric Company had contracted to build the plant for $45,000,000. The plant will be financed entirely through private funds without even a request for a quick-amortization certificate for tax purposes. Commonwealth Edison will put up $30,000,000 and will operate the plant; the other companies will put up the

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remaining $15,000,000 in return for the technical information, experience, and training they will get. On the basis of Commonwealth Edison's $30,000,000 investment, it is estimated that the plant will produce electricity at a cost approximately competitive with new coal-fired genrating units in the company's service area.

The Consolidated Edison Company of New York has also applied to the Atomic Energy Commission for a license to build and operate, entirely with private capital, a 250,000-kilowatt atomic-power plant at an estimated cost of $55,000,000. This is about $220 per kilowatt of capacity, somewhat under the $250 per kilowatt estimated for the Commonwealth Edison project and well within the range of economic feasibility for the New York metropolitan area.

A Fast Start

All this means that the big private-power companies intend to occupy the field fast enough to weaken the argument that the act ought to be further amended to open the way for a federal atomic-power program. As I pointed out in an earlier article for *The Nation,* they are out to forestall any possible atomic Muscle Shoals. They are heeding the warning of Lawrence R. Hafstad, former director of the A. E. C.'s Division of Reactor Development and now consultant to the Chase National Bank, who told the Atomic Industrial Forum last September that it would be prudent for industrial magnates to safeguard their stockholders' money by pushing ahead with atomic-power development instead of letting government organizations do it. He quipped: "If we can get $10,000-a-year government brains to provide the imagination and to take the initiative in this program, then what are all the high-priced vice-presidents in industry for?"

The speed with which we are moving into the era of low-cost atomic power was suggested by W. Kenneth Davis, successor to Hafstad as director of the Division of Reactor Development, in an address to the American Power Conference in Chicago on April 1. Some 2,000,000 kilowatts of atomic-power capacity, Mr. Davis said, would be in service by the end of 1960, about 5,000,000 kilowatts by the end of 1965, about 27,000,000 by the end of 1970, about 83,000,000 by the end of 1975, and about 175,000,000 by the end of 1980, only twenty-five years from now. He added: "Once the transition really begins, I feel it will snowball."

The prediction that atomic-power capacity is due to "snowball" within a very few years can be based only on the assumption that it will be widely competitive with power from conventional low-cost steam plants. What this will mean is suggested by figures prepared by the Federal Power Commission, which show a top cost of 9 mills per kilowatt-hour for electricity produced in the most expensive large steam station built since World War II. Indeed, according to the F. P. C., half of the new steam stations are producing electricity at 6 mills or less.

If, however, the big private power companies dominate this new development, exacting their tolls for the people's use of their own energy resource, public and cooperative electric systems, burdened with old-fashioned high power costs, will face an increasingly difficult time. The right of American communities to choose non-profit electric service, the most important check on private monopoly since the birth of central-station electricity in 1882, will shrivel and die. In other words, since big atomic-power plants are necessary to bring costs down, the people must see to it that the TVA principle is extended to the atomic-power field, for it is imperative to assure to community electric systems a low-cost supply adequate to their expanding needs.

The Alternative

But there must be an alternative attack on the problem in case efforts to obtain a federal program fail. This would require public support for study and development groups working with the Atomic Energy Commission to reduce the cost of small atomic-power plants adapted to the needs of municipalities and rural electric cooperatives. Already there is ground for hope that this objective may be realized by utilizing the experimentation that has gone into the construction of relatively small atomic-power units for the propulsion of naval units, locomotives, and airplanes; there is also what is known as the army package-power reactor.

Fortunately, the country's non-profit electric systems are alert to the need. The National Rural Electric Cooperative Association has a study group approved by the Atomic Energy Commission, as has the Puget Sound Utilities Council, which includes the famous Seattle and Tacoma municipal electric systems and the Chelan and Snohomish Public Utility Districts, as well as the Puget Sound Power and Light Company. The Tennessee Valley Authority is also going forward with studies.

Stopping the Giveaway

Space permits only a brief outline of the steps which should be taken promptly to make sure that attempts to strengthen private-power monopoly by a giveaway of the people's atomic-power resource do not succeed. These steps should certainly include (1) Congressional authorization and appropriation for at least four large federal demonstration plants, constructed under Section 32 of the present act and located where municipal and rural-electric systems are now paying high rates to private systems for their power supply; (2) Congressional authorization and appropriation to enable the Tennessee Valley Authority and other regional power agencies to undertake atomic-power plants under A. E. C. licenses; (3) Congressional provision for loans by the Rural Electrification Administration to rural electric-cooperative groups and associations to finance their research and development activities; and (4) amendment of the Atomic Energy Act of 1954 to restore the power policy and patent provisions adopted by the Senate but struck out in conference.

Action along these lines would do much to bring the development of the people's atomic-power resource under the federal power policy which has produced such outstanding results in the way of lower electric rates, increased consumption of electricity by homes and farms, and healthy expansion of regional economies. Only in this way can we hope to block the extension of a private monopoly which constitutes a serious threat to democracy itself.

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VI. WAR AND PEACE

The moral issues which face us as a result of the two-way nature of fissionable materials are discussed in this section by Kathleen Lonsdale. David Cavers reviews the practical and difficult problems connected with safeguarding fissionable materials for peace-time uses only. Robert W. Frase's remarkable chronology indicates the close relationship between international disarmament and international cooperation for the peace-time development of the atom's potential. The atom, like man, needs peace for development.

THE NEED FOR DECISION

Morality Must Rule . . *by Kathleen Lonsdale*

London

JUST as the laws of a country are effective only when the majority of citizens choose to be law-abiding, so international law, to be effective, must express the intention of at least some governments to act justly, whatever others may do.

It might have been supposed that the legality of using certain kinds of weapons or of experimenting with them in a way to contaminate international waters and the world's atmosphere was a matter that could rightly be considered by the International Court of Justice. The Secretary General of the International Law Association, W. Harvey Moore, in a speech made to the forty-sixth conference of the International Law Association in Edinburgh, August, 1954, declared:

> Nuclear weapons are contrary to international law because, first, nuclear weapons are poisonous, and only barbarians poison their enemies; second, nuclear weapons are inhuman as causing unnecessary suffering; third, nuclear weapons cannot be employed without disregarding the historical distinction between combatants and non-combatants; fourth, nuclear weapons are contrary to the Geneva Convention of 1925 prohibiting the use of asphyxiating, poisonous, or other gases and of all analogous liquids, materials, and devices.

It is clear, however, that this opinion is not accepted by the nations that are stockpiling nuclear weapons. It is questionable in fact whether international law can do more than record and regulate agreements between nations, such as the existing agreements on postal regulations and on the extradition of common criminals.

The nations have spent nearly ten years arguing about the international control of nuclear energy, not because it was impossible to reach agreement, but because neither side believed it to be a matter of sufficient urgency. The Western nations did not think it so urgent that they should risk having to accept the East's increasing preponderance of man-power and their own inability to prevent Communist territorial expansion. The Communist governments did not think it so urgent that they should accept the man-power ratio suggested by the West and allow their uranium industries to be owned, controlled, or limited by a Western-dominated United Nations agency and their country overrun by U. N. inspectors. No one has suggested complete disarmament all round as a practical possibility.

It must be admitted that the enforcement of an international law against a major power accused of violating it would in fact mean war. There is no analogy between a U. N. army and a policeman, for the function of a policeman is not to punish but to bring the wrongdoer to a fair trial, protecting him if necessary against those who would deal with him summarily and without a trial. To call any major war a "police action" is a gross misuse of the term. Is victory in war a proof that justice as been served, or defeat a sign of guilt?

That there is at present no international agreement, enforceable or otherwise, limiting the use of atomic energy to purposes which will benefit mankind does not mean that using them for other purposes is justifiable. Many types of action that are abhorrent to decent people are not and, indeed, cannot be regulated by law.

The Moral Issue

A moral decision represents an individual choice between good and bad, right and wrong. When one has to be made, it is usually influenced by many factors, such as national customs, tribal taboos, early training. In our childhood issues seem clear cut. We are taught that it is right to tell the truth, wrong to tell lies; right to be kind, wrong to be cruel. When we are older, decisions are not so simple. Truth may seem to conflict with courtesy and kindness with military duties or the "right of self-defense." The really difficult question is how to know in any particular set of circumstances what is the right or the wrong thing to do. To refuse to decide is to choose to do nothing. Apathy is a powerful form of action that eases the path of reaction or dictation. We tend to accept a double moral standard: one

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for ourselves as individuals, another for ourselves as nations—moral man, immoral society. But when we are faced as communities by evil situations on all sides, so that any kind of action seems morally questionable, then it is perhaps as well to look at our personal values and practices to see whether they are responsible for the creation of such situations.

We value material comfort and physical security, and attempt to regulate our national affairs so that we will attain these for ourselves and our children. Perhaps those of us who are Christians should remind ourselves that Jesus Christ promised his disciples neither comfort nor safety.

Young people want adventure and an ideal, not safety; we offer them "peace through H-bombs" and tell them it is impossible to be Christian in an un-Christian world. Jesus did not say so. He sent his disciples out "as lambs among wolves." If they had gone out as wolves among wolves, or even as hunters, it is unlikely that they would have found, as they did, that devils were subject to them in Christ's name.

Denial of Truth

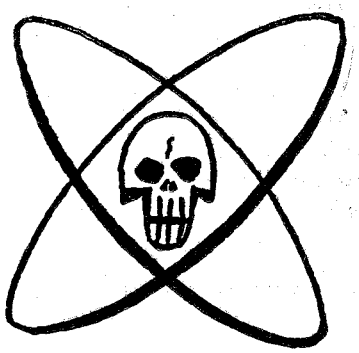
We expect our young people to be horrified at the Marxist denial of God, but we deny Him ourselves by behaving just as we would if He did not exist, did not care, or were helpless. We are afraid that if communism spreads, our children's minds may be conditioned, but we are conditioning them ourselves. When we teach them that truth must be defended by the use of spies and secret agents whose job is to live a lie, that freedom can only be maintained by conscription and military bases while in many countries people are starving, medical supplies are inadequate, and education is rudimentary, that justice may necessitate the use of weapons that will affect the bodies and minds of generations yet unborn, then we are ourselves deliberately confusing these young people so that they do not know good from evil.

We should consider very seriously whether what we are really trying to defend is our democratic ideals or our Western standard of living. Can we defend our ideals by throwing liquid fire over villages and maiming or killing millions of people—innocent children, conscript boys, pregnant mothers? Can we defend our ideals by taking the largest share of this world's goods that we can get, even if it means that others will have only what we throw them with strings attached? "If a brother or sister be naked, and destitute of daily food, and one of you say unto them,'Depart in peace, be ye warmed and filled,' notwithstanding ye give them not those things which are needful to the body, what doth it profit?" As President Eisenhower said in his address to the American Society of Newspaper Editors on April 16, 1953:

> Every gun that is made, every warship launched, every rocket fired, signifies, in the final sense, a theft from those who hunger and are not fed, those who are cold and are not clothed. This world in arms is not spending money alone. It is spending the sweat of its laborers, the genius of its scientists, the hopes of its children. . . . We pay for a single fighter aircraft with 500,000 bushels of wheat. We pay for a single destroyer with new homes that could have housed more than 8,000 people. . . . This is not a way of life at all in any true sense. Under the cloud of threatening war it is humanity hanging from a cross of iron.

It is sometimes argued that unless we are strong we cannot negotiate. But the policy of "negotiation from strength" which is followed by both sides in the world struggle has been responsible for much of the bedevilment of international politics by behavior that seems defensive and reasonable to the side that practices it but aggressive and perverse to the other. When the atomic bombs were dropped on Japan, for instance, any thoughtful geochemist could have foretold the fate of Czechoslovakia. For whereas the West could have easy access to various sources of uranium, particularly in the Belgian Congo and Canada, the Soviet Union would have been relatively helpless if it could not control the Czechoslovakian uranium mines.

What is quite clear, as common sense and simple morality should tell us, is that in the long run we can avoid war and use rightly the world's raw materials, scientific knowledge, and human energy only by abandoning all military weapons, not simply limiting them. This would permit, indeed necessitate, open frontiers,



for there would be no military secrets to hide and openness would be the proof of it. Thus there would be no effective barriers to the movements of populations. Some individuals, of course, would continue to be selfish and greedy, but in the complete absence of military organization, they could not attain great power. Public vigilance could prevent the reestablishment of militarism.

The First Steps

It is equally clear, however, that agreement on complete disarmament will not come for a long time. It can hardly come until nations have devised and put into practice methods of international sharing which prevent gross discrepancies of living standards between and within nations. This is the first step. It would require the training of young people in international cooperation, which could usefully include a period of voluntary, non-military public service at home or abroad. Many young scientists and engineers would gladly spend such a period helping to develop the peaceful uses of atomic energy, especially in technically underdeveloped countries. The second step would be the education of young people in the duty of non-cooperation in community wrongdoing and in the techniques of active but non-military opposition to such evils as racial discrimination, oppression of political minorities, and the occasional inhumanities of bureaucracy. They must not be allowed to make the mistake of thinking that the only alternative to violence is slavery, or to slavery is violence.

Even then the complete abandonment of military organization can only come when enough people are strongly enough convinced either that wars and preparations for war

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are wrong or that they are foolish. It is most likely to come when some nations have sufficient moral courage to set an example.

Certain principles may be enunciated to guide personal and national action, both immediate and long-term.

First, there is only one person whom we can compel to act as we think he should, and that is ourself. If we wait for others to behave better than we do, then we are content to be worse than they.

Second, we should not allow our own right conduct to depend upon the agreement of others to do right. If we wait for that, we may wait forever, and forever is too late.

Third, we must not suppose that behaving well will guarantee our personal safety. Neither Christianity nor any other great religion or ethical system has ever pretended to be an insurance policy.

Fourth, we must not expect that hungry, desperate, illiterate, or primitive peoples will be given a sense of responsibility by the threat or the use of the bombing airplane or by the sight of technically advanced nations continually snarling at each other.

Fifth, we must remember that different nations are at different historical stages. Peoples are not especially wicked because they are going through periods of revolution or imperialism that we have, we hope, outgrown. Nor can such historical stages be bypassed in any easy way.

Sixth, we should realize that the art of negotiation consists in making it easy for our adversary to do what is reasonable, not in humiliating him.

Seventh, it should be no business of decent nations to support corrupt or tyrannical governments.

Finally, when we are tempted to right wrongs by armed force, we should remember that armed force perpetuates the habits of thought that breed oppression and create wrongs; that self-righteous condemnation may only harden the wrongdoer's heart, but that genuine goodness, whether in an individual or in a nation, carries with it a moral force that is irresistible.

WEAPONS OR WELFARE?

Fission Can Go Two Ways . . *by David Cavers*

BACK in 1946 and 1947, when the Baruch Plan was being discussed in the U. N., we were warned that world safety required international ownership of all nuclear material and all plants capable of producing it. The nuclear fuel that would stoke an atomic-power plant was also the nuclear explosive in the atomic bomb. Now we find atomic power moving rapidly toward realization, with atomic-power discussions already under way between the United States and a number of friendly nations. These discussions assume that in a few years we shall be supplying those nations with the nuclear fuel we were so wary about less than a decade ago.

Moreover, after just about the same interval disarmament talks between West and East are showing renewed vitality. In the interim the United States and the Soviet Union have each amassed great stock piles of nuclear explosives; yet demands for international ownership of these volcanic hoards seem to have all but disappeared from the disarmament negotiations.

What has happened? Have the scientists eliminated the hazards, or have we, like the peasants on the slopes of Mt. Etna, simply grown used to living with the risk of being blown up? Unfortunately, the first question can be answered only by those who are not permitted to do so. However, some unclassified speculation may throw light on the problem.

Consider first the "atoms-for-peace" program. That does not depend on the disarmament which we hope it will hasten. Consequently, the United States must face the problem whether it can safely supply foreign nations with the substantial quantities of nuclear fuel needed to supply power reactors, once these become economically practicable. Pretty clearly, Congress will have to be satisfied on the score of safety if it is to tolerate the agreements for exporting the atom that the 1954 Atomic Energy Act authorizes. One precaution is, of course, to supply only our friends. But national regimes and friendships change, whereas the reactors would be built to last at least a decade, perhaps two, perhaps four. Better assurances are to be found in the physical facts.

A nuclear-power plant, whatever its design, does not have to be refueled continuously or even frequently. Indeed, the withdrawal of the partially consumed nuclear fuel when fresh fuel is to be substituted is a costly, difficult task, and the longer it can be postponed, the more economical the reactor's operation. When the fuel is removed, it is highly radioactive and contaminated with fission products, so that it must be carefully shielded and taken away for reprocessing.

Two reassuring circumstances emerge from these facts. In the first place, it will not be necessary to provide power reactors abroad with nuclear stock piles that might be seized for weapons and used in an international crisis. Instead, deliveries of fuel elements can be deferred until those in the reactors are near the end of their burn-up. The fresh elements would then have to be put promptly to work in the reactor lest a large-scale power shutdown occur.

Moreover, once in the reactor, the fuel elements could not be converted

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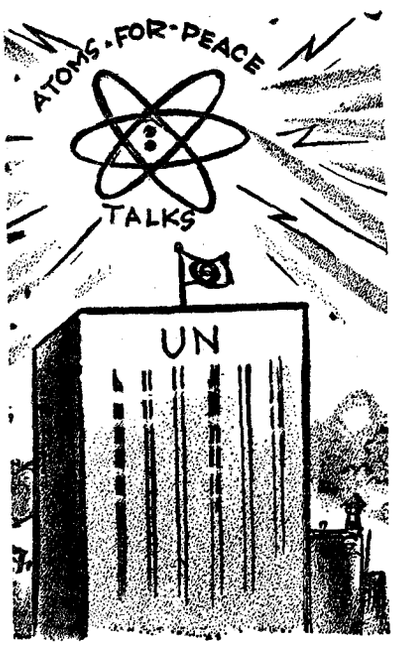


York Gazette and Daily
Progress is being made

readily into bombs. In a short time they would be too hot to handle. This would be even more true of the elements withdrawn for reprocessing at the end of the burn-up. More important still, the new nuclear fuel produced by a converter or a breeder reactor would not emerge from the reactor in a condition permitting its immediate use in atomic bombs.

This fact takes on significance when the functioning of converter and breeder reactors is considered. At the same time that they produce heat for power generation, they produce fissionable plutonium from natural uranium or a fissionable isotope of uranium (U-235) from thorium. The quantities they produce approach, or, in the case of the breeder reactor, exceed the quantity of fissionables (U-235, plutonium, or U-233) they burn up in producing heat. Here then is a possible source of nuclear material for weapons use —but only after chemical separation of the fissionable material from dangerously radioactive impurities, the fission products for which as yet we have found few uses.

These considerations suggest a further precaution. Our agreements for supplying fissionables could reserve to the United States the exclusive privilege of reprocessing fuel elements and of separating fissionables produced in the reactors we had fueled. This is what the government is planning to do in the case of the privately owned reactors now projected for operation in the United States.

There is still another precaution possible, for a time at least. The reactors proposed for construction in the United States are being designed chiefly for the use of uranium enriched by more of the fissionable uranium isotope U-235 than is found in natural uranium. Although U-235 by itself is a nuclear explosive, this combination could be made to create a nuclear explosion with great difficulty, if at all. Fortunately, to separate U-235 from the far more plentiful isotope U-238 requires the material to be run through a gaseous diffusion plant. Probably the United States alone possesses these fantastically expensive facilities, and so we could minimize risks by confining the nuclear fuel we provided to uranium enriched in U-235. However, the coming into use of breeder reactors fueled by plutonium or U-235 and producing plutonium or U-233, all nuclear explosives, would make it impracticable to continue this limitation for an indefinite period of time.

In disarmament planning the main problem springs not from the export of nuclear fuel by the atomically rich nations but rather from the nuclear riches they themselves possess. If we are ever to conceive of a world in which conventional armaments are limited and the possession of atomic and hydrogen weapons is forbidden, we must decide what is to be done with the vast hoards of weapons-grade U-235 and plutonium amassed by us and, in the case of plutonium at least, by the Soviet Union.

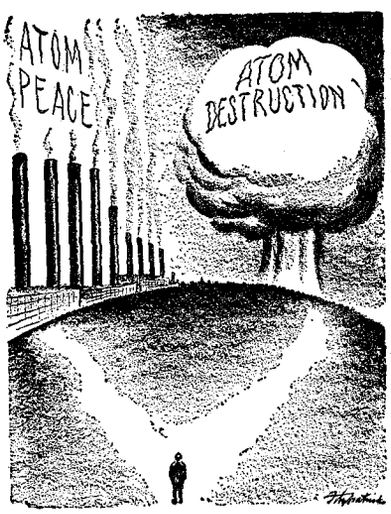
The problem of nuclear stock piles was not difficult for the U. N. in '46 and '47. Our own stock pile then was small, and Russia's probably non-existent. Moreover, in the partially formulated U. N. control plans that the Soviets then rejected, the production of any more fissionables was to await the development of an economic need for them. This was certainly no immediate contingency.

The problem today is made all the more acute by the fact that if atomic explosives are available, atomic bombs can be made, whatever the control plan. No accounting by a control agency could ascertain the number of bomb cases previously manufactured, and future small-scale production would be virtually impossible to detect. As the Soviets put it in the second Assembly resolution they proposed on May 11, "there are possibilities beyond the reach of international control for circumventing this control and organizing the secret manufacture of atomic and hydrogen weapons."

The West's Plan

The British and French at London in May, 1954, had a formula for the stock-pile problem to which we and Canada have now adhered. Our Joint Draft Resolution of March 8, 1955, outlining our whole plan, calls for the "total prohibition and elimination of nuclear weapons and *the conversion of existing stocks of nuclear materials for peaceful purposes*" (italics added). On April 18 the four nations joined in a "Proposal on Nuclear Disarmament" which dealt more specifically with the timing problems, stating that when all nuclear weapons had been destroyed, then "all states . . . shall *convert* and devote their supplies of fissile material to peaceful purposes only" (italics added).

No intimation as to the nature of the happy process whereby atomic explosives can be "converted" to peaceful purposes appears in the verbatim record of the 1954 London meeting of the same subcommittee. Possibly the record of the 1955 meeting will be more revealing. Perhaps no physical change whatever is



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contemplated, and "convert" refers only to changes in purposes. The uncertainty is all the more significant since there is not a single reference to conversion in the Soviet proposals, from that made by Vishinsky in the Assembly last fall down to the three draft resolutions submitted by Malik on May 12, though all of them have picked up many other features of the British-French plan. After atomic weapons are destroyed, the Soviets simply say, "all atomic material will then be used solely for peaceful purposes."

Obviously this declaration, however laudable, carries little assurance. Even conversion does not take care of the atomic material that has not been declared or detected—by whatever accounting methods the control plan calls for. This amount has been estimated at up to 20 per cent of past production. However, conversion does at least offer a way of safeguarding the 80 per cent or more of that past production which honesty or prudence leads each nation to declare.

The conversion idea is not new. It dates back to the Acheson-Lilienthal Report of 1946, the predecessor of the Baruch Plan. Then it was suggested that atomic explosives might be "denatured" in such a way that they could not be used in weapons but still might be used for power. Later it seemed necessary to dampen the excessive hopes that for a time were built on this possibility.

Recently, in setting the statutory "fair price" for nuclear materials produced in private reactors, the United States Atomic Energy Commission has differentiated "weapons-grade" material from nuclear material suitable for use in reactors. However, it is not clear from this that reactor-grade plutonium when used in an A-bomb would not, in a clumsy way, devastate a few square miles and, if combined with lithium in an H-bomb, a few hundred. Moreover, one can only guess whether the weapons-grade plutonium and U-235 that we have in our military stock piles can be downgraded as readily as production can be held below the weapons-grade level.

It seems not unlikely that contaminants could be introduced into weapons-grade materials to render them unsuitable for both weapons and reactors until after chemical refining to eliminate the impurities. If this process were slow enough or required elaborate equipment whose capacity could be limited by the control plan, then a nation's ability to restore the "converted" stock pile to a war footing would be cut down reassuringly. However, the cost of reconverting the material to make it usable again in reactors might be high. Perhaps this explains why the Soviets seem uninterested in conversion.

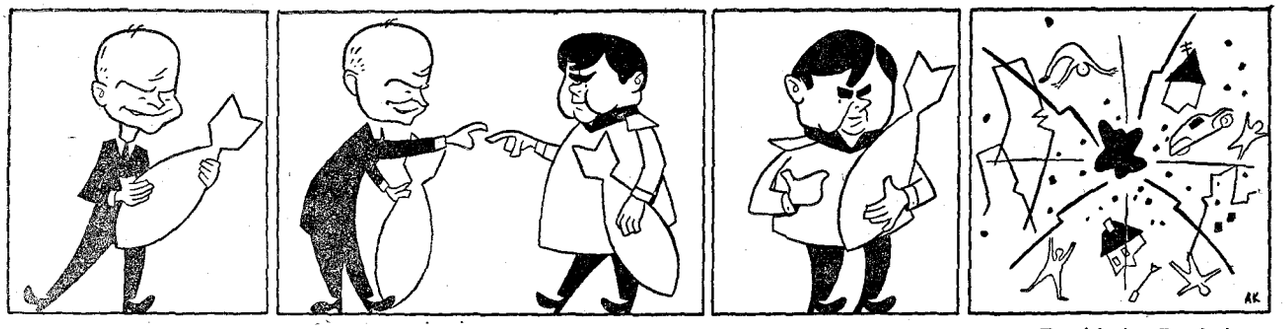
Stock-Pile Problem

Whether stock piles are converted or not, both sides agree that they are to be used only for peaceful purposes. But nothing in the records disclosed thus far reveals whether the stock piles must be used up, or at least be depleted to a reasonable inventory level, before new production of nuclear fuel would be permitted, except perhaps as a by-product in power reactors. Readiness to conform to this requirement might be a better test of good faith than willingness to adopt conversion, yet it might be a hard one for us to accept. It would require the closing down of the huge production reactors at Hanford and Savannah River and of the giant diffusion plants at Oak Ridge, Portsmouth, and Paducah. This would save money, but for certain Senators and Representatives it would be saving money the politically hard way.

How long would it take peaceful consumption to cut back present stock piles to militarily safe levels? Here, of course, one can only guess. But it is obvious that research needs will make only an infinitesimal dent in the stock piles; 100 kilograms of U-235 (not of weapons grade) will keep 15 research reactors abroad operating at least 5 years, A. E. C. Chairman Strauss has announced.

Most of our own projected power reactors will barely be getting under way in three or four years, but they will probably be well ahead of any foreign reactor development we would supply. Moreover, the quantities involved in these four or five ventures will be small in relation either to our military supplies or to our annual output. For example, these reactors may use only U-235; they will leave our plutonium stocks untouched. And if converter and breeder reactors prove practicable, the drain on military stocks for civilian needs will be slowed down by the production incident to reactor operation.

We must face therefore a substantial period when, under a disarmament plan, the world would have more nuclear explosives on its hands than is indicated for its own peace or peace of mind. Conversion may well be the answer, but this prospect makes one look back rather enviously to that Old Testament conversion formula: "They shall beat their swords into plowshares, and their spears into pruning hooks." Plutonium is harder to handle.



Frankfurter Rundschau

I have the bomb *You have the bomb* *He has the bomb* *We have the bomb*

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AN ATOMIC CHRONOLOGY

From Hiroshima to Now . . *by Robert W. Frase*

1945

July 16: First atomic bomb exploded in New Mexico test.

August 6: Second atomic bomb exploded over Hiroshima. Its power equivalent to 20,000 tons of TNT; its area of total destruction, a circle of two miles in diameter, 3.14 square miles.

August 9: Third atomic bomb exploded over Nagasaki.

August 16: Release of the Smyth Report, official account of the wartime development of the atomic bomb and methods of producing fissionable material.

November 15: Declaration in Washington by President Truman and Prime Ministers Attlee and McKenzie King proposing the establishment of a commission in the United Nations to develop a plan for the international control of atomic energy to insure its use for peaceful purposes only.

November 29: General Groves tells Senate committee that the U. S. S. R. would require fifteen to twenty years to produce an atomic bomb by its own unaided efforts, five to seven years if equipment and machinery were supplied by the United States, Great Britain, and Switzerland.

December 5: Russia agrees at Moscow conference to join the United States, Great Britain, and Canada in sponsoring a commission in the United Nations to deal with international atomic control.

1946

January 24: The United Nations General Assembly by unanimous vote accepts the four-power proposal to establish an Atomic Energy Commission consisting of the United States, Great Britain, France, China, Canada, and the U. S. S. R. as permanent members with rotating terms.

January 29: Prime Minister Attlee announces Britain's intention to produce fissionable material.

March 16: Acheson-Lilienthal report released to the press. Technically a report of an Advisory Board under the chairmanship of Dr. J. Robert Oppenheimer to a State Department committee headed by Under Secretary of State Acheson, it proposed to base the control of atomic energy on an international agency owning and controlling all production facilities from mines to electric-power stations. Atomic-power facilities were to be allocated among nations in a "strategic balance" or atomic balance of power. The plan was to go into operation by stages, working up the atomic production ladder from raw materials to reactors.

June 14: First meeting of the United Nations Atomic Energy Commission (hereafter U. N. A. E. C). Presentation of the United States official proposal, the "Baruch Plan," which was the Acheson-Lilienthal plan plus a proposal to remove the great-power veto in the U. N. Security Council so that that body, by a simple majority vote, could impose sanctions for violations of the proposed atomic-control treaty.

June 19: Soviet proposals presented to the U. N. A. E. C. by Andrei Gromyko: an international convention to prohibit the produc-

ROBERT W. FRASE, economist and political scientist, has written about the international control of atomic and other weapons for various British and American journals.

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tion and use of atomic weapons and destruction of completed weapons within three months, to be followed by the establishment of an unspecified system of international control and sanctions for violations.

July 19: U. N. A. E. C. establishes a Scientific and Technical Committee consisting of the scientific advisers to its several delegates. This reported unanimously on September 27 that it did "not find any basis in the available scientific facts for supposing that effective control is not technologically feasible."

December 14: Unanimous resolution of the U. N. General Assembly establishing a Commission on Conventional Armaments, with the same membership as U. N. A. E. C., to work on problems of arms control for non-atomic weapons and armed forces.

December 30: First Report of the U. N. A. E. C., nine affirmative votes and two not voting (U. S. S. R. and Poland). While following generally, so far as it went, the United States proposal of the previous June, the report did not require international ownership of all stages in the atomic-production process.

1947

January 5: Baruch resigns as United States delegate to the U. N. A. E. C. and is succeeded shortly by former United States Senator Warren Austin, with Frederick Osborn as deputy and day-to-day negotiator.

February 18: Gromyko proposes amendments to the First Report of the U. N. A. E. C., the substance of which was to reject the United States proposal on stages and to insist that whatever form of international control was agreed on would have to be applied to all stages of the atomic-production process at the same time; to reject the idea of international ownership and management; and to indicate acceptance of only some weak form of international inspection.

June 11: Formal Russian proposals presented by Gromyko—accepting an internationally staffed control commission but rejecting international ownership and management of all atomic-production facilities. Inspection for compliance to be only "periodic," with special investigations on any suspicion of violation. Rejected by the U. N. A. E. C. majority.

July 7: Meetings of the various committees of the U. N. A. E. C. thrown open to the public, symbolic of the termination of serious East-West negotiations in the commission.

September 11: Second Report of the U. N. A. E. C. approved nine to one (U. S. S. R.), with Poland abstaining. This is the so-called "majority plan," which remains to this day the most detailed elaboration of an atomic-control plan adopted in the United Nations. The plan spells out at some length international ownership of atomic-production facilities, except uranium mines, and sweeping inspection arrangements designed primarily to detect possible illegal and clandestine production facilities. It advises against any large-scale production of plutonium until the technical and economic feasibility of electric power from atomic energy is demonstrated. The plan contains no significant details on the atomic-production quotas to be allowed individual countries, on the international control agency, on timing of the stages for putting it in operation, or on the matter of sanctions for violations of the control plan.

November 7: Molotov announces that the U. S. S. R. has uncovered the "secret of atomic energy."

1948

May 17: Third Report of the U. N. A. E. C., containing no new substantive material and designed primarily as a procedural vehicle for transmitting the First and Second Reports to the U. N. General Assembly.

June 22: First Soviet veto in atomic-energy matters, cast in the Security Council vote on approval of the first, second, and third reports of the U. N. A. E. C.

November 4: Resolution of the U. N. General Assembly indorsing these reports, directing the U. N. A. E. C. to continue work, and requesting its permanent members plus Canada to engage in private consultations and report back to the next Assembly session. The original Western motion, put forward by Canada, to discontinue the work of the U. N. A. E. C. was withdrawn when it became apparent that it would not be accepted. In the Assembly debate Russia withdrew its insistence that prohibition of the use

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of atomic weapons precede control of such weapons—subsequently withdrawn and reinstated at intervals.

1949

September 23: First atomic explosion in U. S. S. R. announced by United States and British governments and later confirmed by the Tass news agency.

October 24: Report issued on the six-power private consultations ordered by the U. N. General Assembly: no progress reported.

November 23: Resolution of the U. N. General Assembly recommending continuing consultations of the six permanent members of the U. N. A. E. C.

1950

January 31: President Truman announces that work on the hydrogen or super-bomb will be pressed by the United States.

June 14: Start of the Korean war.

July 1: First large-scale British plant for production of plutonium placed in operation at Windscale.

October 24: President Truman, addressing the U. N. General Assembly, states that a successful disarmament plan must cover all types of weapons and proposes that the U. N. A. E. C. and the U. N. Commission on Conventional Armaments be merged, a reversal of the position held by the United States since 1947 that atomic-energy control must precede control of conventional armaments and armed forces.

November 17: U. N. General Assembly votes to establish a Committee of Twelve to consider United States proposal for the merging of the two commissions and to report back to the next Assembly.

1951

October 6: Stalin in *Pravda* interview states that U. S. S. R. has recently tested another atomic bomb and that further tests of atomic bombs of different calibers will be made.

October 23: The Committee of Twelve recommends to the U. N. General Assembly acceptance of the Truman proposal to merge the U. N. A. E. C. and the Commission on Conventional Armaments into a new Disarmament Commission.

November 18: British-French-American proposals to U. N. General Assembly, suggesting in addition to the merging of the two commissions a progressive disclosure and verification of all armaments and armed forces as the first and indispensable step in a general program of atomic and conventional arms control.

December 11: Results of four-power private discussions (United States, Great Britain, U. S. S. R., France) during U. N. Assembly session reported. Major differences between the Western powers and the U. S. S. R. reported at this stage to be Soviet insistence on one-third reduction of general armaments from present levels instead of balanced absolute quota, Soviet insistence on prohibition of atomic weapons as first step, Soviet objection to inspection on a continuing basis, Soviet unwillingness to accept the "majority plan" as basis for atomic control.

1952

January 11: U. N. General Assembly adopts revised version of British-French-United States resolution by forty-two affirmative votes to five (Soviet bloc), with seven not voting. This version set up a new Disarmament Commission and provided as its terms of reference an arms census, balanced reduction of conventional armaments, and the U. N. "majority plan" as the basis in principle for atomic control.

January 12: New text of Soviet proposals presented to U. N. Assembly by Vishinsky—no essential change except that prior prohibition of atomic bombs once more withdrawn. Referred to new Disarmament Commission.

March 14: First meeting of new U. N. Disarmament Commission. United States proposals for agenda put forth by Benjamin Cohen, the new United States delegate. They would require progressive disclosure of armaments and their verification by international inspection before the commission would take up the substance of conventional arms quotas or the details of atomic-energy control. Modified on April 5 to include atomic weapons in the disclosure.

May 28: British-French-American paper submitted to Disarmament Commission proposing first specific quantitative limit on armed forces put forward in U. N. negotiations: between 1,000,000 and 1,500,000 men for the United States, U. S. S. R., and China, 700,000 for Britain, 800,-

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After his execution, when his body was brought to Chicago, 30,000 people marched in the funeral procession. For some years after his death much was written about his articles, poems and songs. Then a curious silence descended. Though his songs continued to be sung—though his memory was kept alive in the immortal lyrics of Alfred Hayes "I Dreamed I Saw Joe Hill Last Night"— the real man began to fade into myth.

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000 for France, with 1 per cent or less of total population for other countries. Rejected by U. S. S. R.

October 23: First British atomic test explosion.

November 16: Atomic Energy Commission announces conclusion of atomic tests at Eniwetok in Pacific, including experimental thermo-nuclear (hydrogen bomb) device.

1953

March 5: Death of Stalin.

April 8: Resolution of the U. N. General Assembly directing the Disarmament Commission to continue its work and report to the Security Council and General Assembly not later than September 1.

April 16: President Eisenhower in speech to American Society of Newspaper Editors sets forth United States position on arms control: limitation of armed forces of all nations by absolute numbers or agreed ratio; limitation of strategic materials devoted to military purposes; prohibition of military use of atomic energy; limitation or prohibition of other major weapons; enforcement by adequate safeguards, including inspection by international agency.

April 25: Eisenhower speech printed in full in *Pravda,* with editorial approval of the five principles in general.

August 25: Pravda announces Russian test of hydrogen bomb, "many times greater than the power of atomic bombs."

November 18: Resolution of the U. N. General Assembly directing the Disarmament Commission to continue work and recommending private talks on the subject by major powers.

December 8: In a speech to the U. N. General Assembly, President Eisenhower presents "Atoms for Peace" proposal, an international pool of contributed fissionable material for research and development of the peaceful uses of atomic energy. States that United States has conducted forty-two test atomic explosions and that the United States stockpile of atomic weapons exceeds explosive equivalent of all bombs and shells used in the six years of World War II.

1954

March 1: United States hydrogen bomb tests in Marshall Islands in Pacific.

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March 13: Japanese fishing trawler Fukuyuru Maru docks in Japan with twenty-three crew members suffering from radiation exposure caused by fall-out from March 1 test at a distance of 80 to 90 miles.

March 31: The chairman of the United States Atomic Energy Commission announces that the hydrogen bomb tested on March 1 had about twice as much power as was calculated in advance.

Western Proposals

June 25: Conclusion of the private five-power talks of the subcommittee of the Disarmament Commission in London that were started on May 13 in accordance with Assembly recommendation. Subsequent release of the records indicated that the United States had put forward more detailed proposals on the international control agency than hitherto and that the British and French had made a new detailed proposal on the four stages of disarmament and atomic control: creation of a control body; freeze of military man-power and military expenditures at 1953 levels; reduction of conventional armaments and armed forces to half of agreed quota; cessation of manufacture of nuclear weapons, reduction of conventional armaments by remaining half to agreed quotas, and conversion of all nuclear materials to peaceful purposes. The Soviet reaction was noncommittal.

August 20: Dr. Mervin J. Kelly, consultant to the United States Defense Department, tells a meeting of the United States Air Force Association that *fission* bombs with a force equivalent to five million tons of TNT (250 times the power of the Hiroshima bomb and using little more fissionable material) have been developed; also *fusion* bombs with up to 40 times the force of the largest fission bombs (10,000 times the power of the Hiroshima bomb).

September 6: Ground-breaking ceremonies for first United States full-scale atomic reactor for electric-power production at Shippingsport, Pennsylvania.

September 30: Vishinsky makes new proposals to U. N. General Assembly, accepting British-French proposals on timing as point of departure, but differing in such details as no initial freeze of armaments and concentrating all action in two stages definitely delimited in time. In the debate the British and French delegates raised a new question—whether it is now practical to devise an effective means of international atomic control that would take account of past production of fissionable material and its possible concealment for use in bombs.

October 20: Announcement by the chairman of the United States Atomic Energy Commission that there had been a series of nuclear explosions in Soviet territory beginning in mid-September and continuing at intervals, with widespread fall-out of radioactive material.

November 4: The U. N. General Assembly approves unanimously a resolution urging the Disarmament Commission to continue its work and recommending further talks in its big-power subcommittee.

November 15: The U. N. Assembly debate begins on Eisenhower's "Atoms for Peace" proposal. Because of Soviet unwillingness to participate this had been modified to eliminate an international pool of fissionable material and substitute a U. N. agency acting as a clearing-house to distribute donations of fissionable material. The United States offers to contribute 220 pounds of fissionable material (U-235 or plutonium content); the British offer 44 pounds.

Resolution Approved

December 4: The U. N. General Assembly approves revised "Atoms for Peace" resolution: (1) setting up as a specialized agency of the U. N. an International Atomic Energy Agency for the development of peaceful uses; and (2) authorizing the Secretary General to call an international conference on peaceful uses not later than August, 1955 (Geneva Conference).

1955

February 15: The United States Atomic Energy Commission announces that the March 1, 1954, hydrogen-bomb test in the Pacific demonstrated power which can be estimated as sufficient to destroy or seriously damage or destroy all buildings within a circle with a diameter of from 12 to 24 miles (113 to 452 square miles, or 36 to 144 times the number of square miles destroyed by the Hiroshima bomb). The radioactive fall-out would contaminate an elliptical area down wind extending some 140 miles and covering some 7,000 square miles to an extent requiring evacuation or taking shelter.

February 17: Churchill announces that the British will make hydrogen bombs.

March 4: Estimates published in New York *Times* setting United States' A-bomb stockpile at more than 5,000 and U. S. S. R.'s at from 500 to 1,000.

March 19: President Eisenhower announces appointment of Harold Stassen as his special assistant to coordinate plans for disarmament.

May 11: The Soviet news agency Tass releases a draft resolution proposed for adoption by the U. N. General Assembly and submitted the previous day to the major-power subcommittee of the Disarmament Commission which had been meeting in London since late February. The Soviet draft for disarmament in two stages included the following further concessions in the direction of the Western position, especially the British-French proposals of June 11, 1954: (1) acceptance of a preliminary freeze of existing forces; (2) agreement to the specific numerical limitations on armed forces first proposed by the Western powers in May, 1952; (3) agreement on permanent resident international inspectors. The newest Soviet suggestions still diverge from the Western proposals in requiring the abolition of foreign military bases, in the details of what is to be included in each of the disarmament stages, in the addition of a ban on atomic tests along the way, and in the failure to specify unlimited access to the international-control inspectorate. They contain some recognition of the problem of accounting for past production of fissionable material—the difficulty of discovering secret caches of fissionable material even with more or less unlimited inspection.

May 17: The United States Atomic Energy Commission announces a successful underwater nuclear test explosion in the Pacific, bringing to sixty-six the number of nuclear bombs and devices exploded by the United States, sixteen of them in 1955.

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VII. ROLE OF THE UNITED NATIONS

THE ATOM IN THE U.N.

Power or Power Politics? . . *by Victor H. Bernstein*

IT IS natural that people's hopes for international cooperation in the development of peace-time uses of atomic energy should be centered in the United Nations. It was before this body that the first formal proposal for international atomic control and development—the Baruch Plan—was laid in June, 1946. It was before the same body, four years later, that President Truman, borrowing from the late Senator McMahon's imaginative "global Marshall plan" based on atomic energy, proposed that after a "fool-proof" disarmament agreement was reached, the money saved on armaments could be spent on a "pooling of resources" in a war against want. And it was before the U. N. that President Eisenhower, on December 8, 1953, laid the groundwork for the two current major international developments in the peace-time use of atomic energy: the Geneva scientific conference which meets in August, and the International Atomic Agency, now in process of formation. The conference and the agency are themselves provided for in a resolution passed by the General Assembly on December 4, 1954.

Thus the role of the U. N. as guide and mentor for the world's entry into the atomic era would seem to be assured. In truth, it is nothing of the sort. Speeches and resolutions, however eloquently they may express the hopes of mankind, are no match for the national self-interests which still shape international conduct. Unless public opinion forces a basic change, the future of the atom will be charted less in the U. N. than in Pentagons, chancelleries, and industrial laboratories of the have nations; for the have-nots, the U. N. will offer little beyond libraries of learned formulas, some blueprints for reactors which they now have neither the money nor the resources to build, and an international forum from which to air their grievances.

In only eighteen months, under the impact of *Realpolitik*, the President's atoms-for-peace proposal has itself undergone a kind of non-nuclear fission, and today it bears hardly more than an historical affinity to its original form. To understand what has been happening, one must recall the circumstances under which the President spoke. With disarmament talks at a stubborn deadlock, the world was watching with growing horror as the United States and the Soviet Union competed in the building of bigger and better nuclear weapons. In the meantime the security provisions of the first Atomic Energy Act were proving more embarrassing to our allies, it would seem, than to our potential enemies. Certainly the British, who had done much to help develop the bomb which smashed Hiroshima, were eyeing the American uranium curtain with increasing restiveness. So were the Belgians, who supply Washington with much raw uranium. It is worth noting that

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Mr. Eisenhower appeared before the General Assembly fresh from his meeting with Sir Winston Churchill in Bermuda.

The operative paragraphs of the President's plan, as delivered before the General Assembly, were as follows:

> I therefore make the following proposal:
>
> The governments principally involved, to the extent permitted by elementary prudence, to begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic-agency. We would expect that such an agency would be set up under the aegis of the United Nations. . . .
>
> The more important responsibility of this atomic-energy agency would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine, and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world.
>
> Of [the nations] principally involved, the Soviet Union must, of course, be one. . . .

Presented in the context of a disarmament speech, the plan seemed a brilliant maneuver to bypass the disarmament deadlock and achieve the same goal by other means. Indeed, in urging his plan Mr Eisenhower pointed out that the formation of an atomic pool for peace-time use would serve to "divert" fissionable materials from war-time use. But hopes that the plan could slow down the atomic-weapons race were short-lived. "This is outside our terms of reference," said an American delegate at the U. N. disarmament sub-committee meeting the following May. With the supply of fissionable materials increasing at a steadily accelerating rate, how could a minute contribution to an atomic pool check the building of nuclear weapons?

The absolute separation between the President's plan and any and all disarmament proceedings was soon officially confirmed both in Washington and at the U. N. What the President was proposing, in effect, was the erection of an atomic-energy paradise in the shadow of the atomic bomb. One could only hope that the

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paradise would be completed before the bomb went off. But within its limitations, the President's was an imaginative gesture, and was so received by most nations—particularly that part of it which promised to provide "abundant electrical energy in the power-starved areas of the world." What is so tragic is that it ended up as no more than a gesture; its weakest defenders were the Americans themselves. The Russians, of course, headed the overt opposition, arguing that to disseminate fissionable materials and nuclear know-how throughout the world without first reaching an agreement on disarmament and international atomic controls was to invite the building, not of fewer bombs, but of more. They also demanded that the proposed agency be made responsible to the Security Council (and thus subject to veto). The Soviet representatives pressed home their viewpoints with remarkable logic and with an equally remarkable insensitivity to world opinion. For it was clear from the beginning that while nations everywhere wanted disarmament, most also wanted the President's plan and were in no mood to sacrifice the one because they could not get the other.

Repeated attempts by the small nations to put some flesh on the bones of the President's proposals failed. How could they succeed when the Americans would not help? Quietly the President's idea that a "special purpose" of the agency would be to "provide abundant electrical energy in the power-starved areas of the world" was allowed to fade. This is not surprising: if Washington is reluctant to distribute wheat to hungry people through the U. N., why should it distribute electric power that way? And there was a meeting of minds among the uranium-producing nations—extending, to some extent, across the iron curtain—that it might be unwise to entrust the agency with actual possession of the atomic pool. So the President's plan was amended in another direction: fissionable material would not be "allotted" to the agency, but would be "earmarked" through it for direct delivery to a specific beneficiary. "The agency," said the British representative in the U. N.'s Political Committee, "would be a broker, not a banker."

The question of the relationship which the agency is to bear to the U. N. has not been solved. Opposing the Soviet demand that it be subsidiary to the Security Council, Washington and most of its allies sought to give it the status of a specialized agency, such as the World Health Organization, which is responsible to the General Assembly and to the Economic and Social Council. In the end, at the suggestion of India, the General Assembly approved a resolution which "suggests that, once the agency is established, it negotiate an appropriate form of agreement with the United

COMPLIMENTS

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Nations." This is the agency which, according to Eisenhower's original plan, was to have been formed "under the aegis" of the U. N.

Nor was this the last distortion of the President's proposal. Eisenhower had clearly said that the Soviet Union must be one of the nations involved in the setting up of the agency. But Russian recalcitrance angered the Americans, who decided to go ahead with or without Moscow. Talks on the formation of the agency are now proceeding among the United States, Australia, Belgium, Canada, France, the Union of South Africa, and the United Kingdom—all uranium-producing nations. Apparently it is hoped to present the Russians with a fait accompli. If you ask at the United Nations about the progress of these discussions, you will be told: "The International Atomic Agency is not our baby; direct your inquiries to Washington."

U. N. Is Left Out

Will it ever be really the U. N.'s "baby"? In the course of the debate in the Political Committee, the Norwegian delegate remarked:

> It was clear that the uranium-producing nations would hesitate to empower the international agency to dispose of one of their most valuable assets, and such an arrangement could not be contemplated. On the other hand, the consumer nations clearly wish to have access to the necessary raw materials and information. Lastly, it is desirable that the U.N. should participate in the contemplated agreement, and it would seem desirable for countries which have no access to raw materials to be represented in the negotiations on the establishment of the agency

The U. N. is not participating in the agency's formation, and neither are the nations which have no uranium. The relationship to be created between the agency, once it is established, and the U. N., will reflect these facts. The uranium will continue to belong to its producers, and its producers will determine where and how it shall be used. The rest will be window dressing until such time as an international disarmament and control plan have been reached. Meanwhile the United States and Britain have scored a propaganda victory by earmarking the first contributions to the atomic pool. But it is Washington, not an international authority which is determining how the American contribution is to be distributed. Similarly the President's new offer last week of experimental reactors and "know-how" to free nations is also based on the principle of bilateral rather than collective agreement.

The Geneva Conference

Like the international agency, the scientific conference to be held in Geneva was an American idea. Unlike the agency, it has become truly a U. N. enterprise. But valuable as it will undoubtedly prove, its functions do not measure up to President Eisenhower's broad international concept as expressed in his 1953 speech. The agency and the conference were discussed at the U. N. under the agenda title: "International cooperation in developing the peaceful uses of atomic energy: report of the United States of America." At one point in the debate, the Norwegian delegate remarked:

> The United States representative proposed that the conference should discover the field in which progress would be technically feasible and develop procedures whereby the nations of the world could make known their wants. The development of procedures whereby nations could make known their wants is clearly a very different matter from the development of the peaceful uses of atomic energy through international cooperation.

What the Norwegian was saying, of course, was that while the conference might very well serve to uncover needs, it was not prepared to provide ways to supply them. And indeed it is not. The conference will be a twelve-day assembly of most of the world's greatest scientists who will exchange information on every conceivable phase of the peace-time uses of atomic energy. There will be a plethora of cranium and no uranium. It must report its findings to the U. N., but without recommendations or resolutions. The papers presented must be purely technical, scientific, and apolitical, which means that the delegations from the have-not nations will depart the conference stuffed with scientific lore which they will not be able to apply unless they go elsewhere to get the uranium or money. And on the one aspect of atomic energy most important to world peace and the war on want—the application of nuclear power to underdeveloped areas—the conference will be all but mum. Of the 166 hours of scheduled discussions on the agenda, the time allotted to this subject is part of a three-hour closing plenary session.

Even so, the Geneva meeting will be on a grander scale than anything contemplated at the outset by its originator, the United States. In the early planning stages, the Americans were talking in terms of an agenda limited largely to isotopes. But the plan captivated the world's imagination, even as did President Eisenhower's atoms-pool plan, and this time with more results. The agenda grew; papers are pouring in from all parts of the globe. The Russians, Americans, and British are vying for space for government exhibits re-

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lating to atomic energy. Private industry has been titilated; it will have an international exhibit of its own in downtown Geneva, away from the site of the conference. The U. N. has a thriving enterprise on its hands. Yet it could be that the conference's ultimate significance will evolve outside the purview of the world organization. For in a real sense the meeting provides a springboard for the entry of private enterprise into the atomic era on an international scale. Except for classified military material, there will be not much left of the uranium curtain by the time it is finished. The atom will have been stripped of its mysteries, at least for peace-time uses, and subject only to national security considerations, the industrial giants of the world can get to work exporting reactors.

The show seems to be running away from its planners. Despite the agenda's injunction, there is doubt that it can be kept apolitical. The very fact that the delegates will attend as representatives of governments rather than as individuals creates a political atmosphere. If they are enjoined from making collective decisions, there is nothing to prevent them from reaching individual ones, formally or informally. The dynamics of the situation are creating pressures on both East and West to turn from their cold war rivalry into the constructive channels of peaceful competition.

Needed: Point 4 Plan

This is all to the good, yet one is constrained to ask: could it not have been better? It is true that the benefits of the first industrial revolution, fostered and carried through by private enterprise, were eventually shared in some degree by most of the people in the world. But how rapidly and how equitably? And how rapidly and equitably will the world's peoples share in the vast potential of the atom so long as it is exploited in the interests of politics and profits? It is within this context, of course, that the proper role of the U. N. in the atomic era becomes clear. What other international body is capable of thinking in terms of human needs rather than national interests or private profits? What other body is better prepared to send the atom not where it will make the most money, but where it will do the most good?

What is needed, as a beginning, is a U. N. Point 4 Plan. The outlook is not propitious, if only for the reason that the Russians have already introduced a proposal of this kind for discussion at the next General Assembly. But it is far from hopeless. An aroused public opinion forced East-West agreement on the resolutions of 1954 which provided for the Geneva conference and the international atomic agency. An aroused public opinion can force agreement again in 1955. And this time, an alert American industry, motivated by self-interest, will throw its weight behind any U. N. plan, be it called Point Four-A or Atomic Technical Assistance or whatever, which promises to broaden the market for the inexhaustible atom.

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BOOKS

Ninety Years of *The Nation*

By Kenneth N. Stewart

THE battlefield of liberal journalism is strewn with the neglected graves of high-minded and short-lived periodicals, nobly conceived and ignobly buried. Precious little in newspapers and magazines today reminds readers that the American free press was born of protest and revolt.

Time and time again men and women of vision and talent have dedicated their dreams and their energies, sometimes their fortunes and even their lives, to the proposition that freedom of the press and democracy itself can survive only so long as responsible dissent is kept alive. At periods throughout our history it has been a bitter battle and often a losing one. There have been many signs on all sides in recent years that this may well be one of those periods. It is heartening then to be able to point to at least one champion of not always popular men and ideas, one challenger of dogma and orthodoxy, one publication that has survived adversity and animosity for almost a century and still dares to print what it believes despite the climate of conformity.

For ninety years now *The Nation* has carried on in the independent tradition of its founders, escaping the fate of so many of its fellows.

On July 6, 1865, three months after the end of the Civil War, the first issue of *The Nation* appeared, editorially committed to the elevation of the newly freed men of the South, as well as to the accurate discussion of public affairs and the diffusion of democratic principles.

It seems significant that the Supreme Court's desegregation decision should have come at the time when *The Nation* was preparing to observe its ninetieth birthday. *The Nation's* first editorial pledge was to the cause of equality for the Negro. What better yardstick than the race question remains for measuring the true degree of devotion to the principles of freedom? *The Nation* is in the forefront of that fight today as in 1865.

That is not to say that *The Nation* has at every stage in its long life stood for policies which every modern liberal might embrace. For a single instance, it once opposed woman suffrage (later espousing it with special vigor). Taking *The Nation* to task for specific stands it may have held on isolated issues is, however, beside the point—that is, if we think of liberalism as an attitude, not a program, if we grant that liberals ought never become so irrevocably attached to any plan or any man, to any party or any policy, that they cannot change with the changing times. Any other concept of liberalism sacrifices the liberal's valuable function of keeping democracy dynamic and mutable. If we look not so much for consistency in causes as for constancy in principles and practice we shall soon see that *The Nation* has lived up to its lofty heritage and met the test of the years unflinchingly.

This changing quality, this flexibility reflected in the pages of *The Nation*, is ably and dramatically illustrated by Alan Pendleton Grimes, associate professor of political science at Michigan State College, in his scholarly monograph on "The Political Liberalism of the New York Nation, 1865-1932."*

"The development of American liberalism since 1865 has not been a systematic process but rather one that has proceeded with mighty spurts and occasional retrogressions," he writes. "No better portrayal of this movement, with its high ideals and frequent flaws may be found than in the files of *The Nation* magazine."

Although Professor Grimes brings

KENNETH N. STEWART, professor of journalism at the University of Michigan, is the author of "News Is What We Make It" and co-author with John Tebbel of "Makers of Modern Journalism."

*The James Sprunt Studies in History and Political Science Volume 34. The University of North Carolina Press.

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the story only up to the beginning of the present editorship, which happened to coincide with the depression and the birth of the New Deal, readers of the magazine can write a fitting sequel themselves from what they see in its pages today. "Here, encompassed in the span of one journal's life," Freda Kirchwey has written, "you find the whole story of freedom's struggle to adapt to, and so survive, the inexorable growth of industrial collectivism." By way of introduction Professor Grimes notes that the editor of such a periodical, "dealing with present politics rather than history, with contemporary personalities rather than past heroes, with rights endangered and wrongs to be rectified, with the whole machinery of government in motion, writes of the excitement and vibrancy of history in the making, and his periodical may become not only a source of history, but one of its makers."

Outstanding among editors who made history was Edwin Lawrence Godkin, who founded *The Nation* and directed it from 1865 to 1899. Godkin was an intellectual of extraordinary integrity, who deeply influenced the thinking of the educated minority. Under him *The Nation* was a brilliant but unprofitable journal which eventually became a weekly edition of the New York *Evening Post*.

At a time when the circulation warfare of the yellow journals was misleading masses of readers and making a mockery of enlightened citizenship, the opinions of Godkin, who reached only a comparative handful of subscribers directly, penetrated to the farthest corners of the country through other newspapers, from ministers in their pulpits, out of the offices of college presidents, in the thoughts and speeches of public men, until they eventually reached the masses, who had never heard of their author. When Godkin died in 1902, Charles Eliot Norton, who had helped get the magazine on its feet, wrote: "He did more than any other writer of his generation to clarify the intelligence and to quicken the conscience of the thoughtful part of the community in regard to every important political question of the time."

After a series of editorial shifts Oswald Garrison Villard took over the editorship of *The Nation* in January, 1918. In July of that year he sold the New York *Evening Post*, which had been affiliated with *The Nation* since 1881, and they went their separate ways. Villard retained active editorship of *The Nation* until 1932. Under the interim editorships, according to Grimes, *The Nation* had lost a good deal of the verve and the flavor it possessed under Godkin and was to regain under Villard. Those other editors were "as much academicians as journalists, and their work reveals more of an ardent scholarship than a zest for contemporary political life."

Crusading Zeal

Villard, educated at Harvard, where he taught American history from 1894 to 1896, revived *The Nation's* crusading zeal and "made more acres of public men actually miserable, per unit of circulation, than any other editor alive." He reinstated the ideals, if not all the ideas, of Godkin, of whom he wrote: "Almost every one of the reforms in government of our day Godkin championed, and always by going to the root of the thing, by seeking the underlying principle and setting it forth." This was the model and the inspiration set before Freda Kirchwey when she joined *The Nation* under Villard in 1918. She became vice-president in 1922 and served as managing editor from that year until 1928, then for two years as literary editor. After Villard retired in 1932, a board of editors directed the paper until 1937 when she took over as editor and publisher.

Through the personalities of its editors and through the developing pattern of *The Nation's* political editorials and comments, Professor Grimes traces the transition in American thought from a formalized liberalism to a flexible progressivism.

> The old liberals, clinging to a static concept of economic rights that took little cognizance of economic changes, believed liberty to exist whenever government regulation was absent [he comments]. The new progressives, basing their concept of economic rights on current economic conditions sought positive government assistance to make more meaningful the phrase "equality of opportunity." . . . The old liberals, identifying liberalism with capitalism, resisted any governmental alterations of the eco-

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nomic system. The progressives, identifying liberalism with social democracy, sought to modify capitalism in order to extend liberty....

Within the framework of the old liberalism, the Godkin Nation fought the good fight for human freedom, honest government, and a pure society. Within the outlines of progressivism, the Villard Nation carried on the same struggle.

Whereas the old Nation seldom made an issue of civil liberties, the new Nation scoured the country for instances of their denial and gave them full publicity. . . . The new Nation flaunted its banner of freedom in the face of the Ku Klux Klanism, 100 per cent Americanism, and the super-patriotism of the twenties that found all dissenters subversive. It espoused the freedom of men to speak and write about James Joyce, Soviet Russia, and free love; it defended Henry Ford's right to expound anti-Semitism. It reaffirmed the old faith in truth discerned through free discussion. It fought for the release of conscientious objectors from concentration camps, an executive pardon for Mooney and Billings, and a new trial for Sacco and Vanzetti. Within the framework of progressivism it fought for equality, freedom—social, political, and economic—and democracy. Though it seldom won its battles, it nevertheless served to keep alive the tenets of liberal democratic faith in an age that saw that system on the wane.

This is the heritage *The Nation* honors as it enters the final decade of a century of continuous publication. Never was the full and fearless exercise of that heritage more important. At a time when a reputable newspaperman can land in jail for helping a Negro buy a house in a white neighborhood, when once again dissenters are suspected of subversion, and faith in free and open discussion falters, today as in the twenties and other times past the nation desperately needs *The Nation.*

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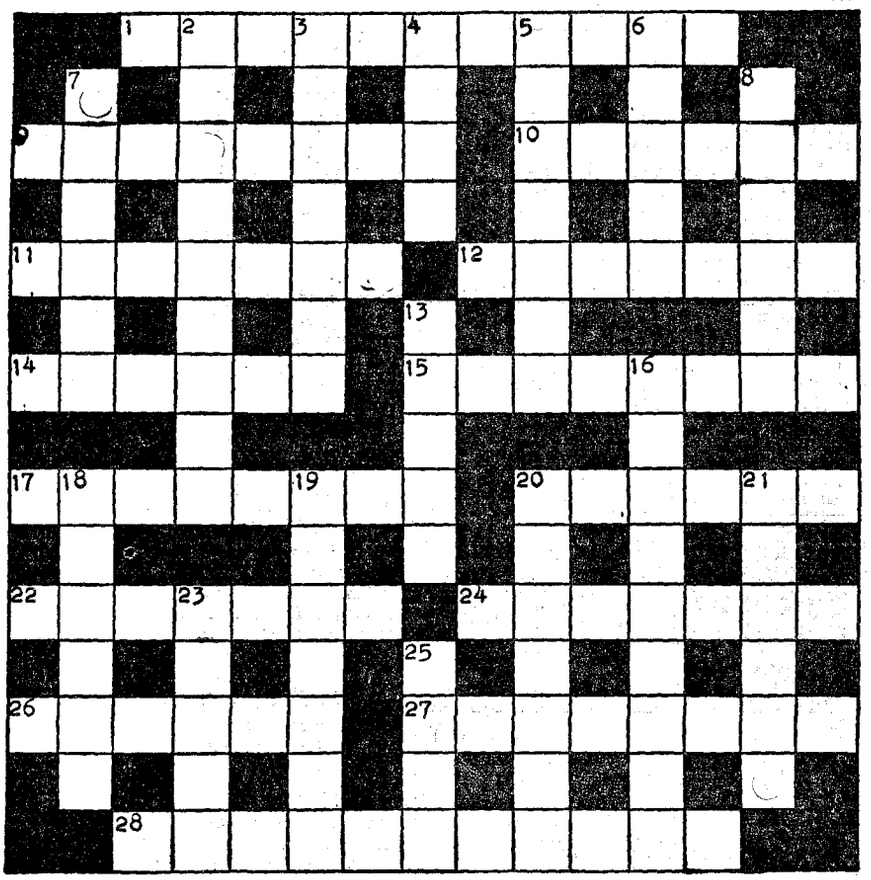

ACROSS

1 See 11 across
9 Vain, in a way—took off and disappeared completely! (8)
10 See 14 across.
11 and 27 and 1 across It appears that zero follows after, as a diplomatic lake. (7,8,4,7)
12 Puckish fools? (7)
14 15 and 10 across Tom has to be sacked before you can. (3,3,3,3,2,-3,3)
17 Knock at the temple? (8)
20 A hundred to one it's in a sort of free port of Brazil! (6)
22 Beats what some riders will hang on to! (7)
24 Did one a turn, but might prove troublesome. (7)
26 He's a prime reason for getting needled! (6)
27 See 11 across.
28 Implying nothing is shady when it comes to emotions! (4,2,5)

DOWN

2 This wire's confused with the dish! (5,4)
3 Intensify it, hence an alteration is necessary, though slight. (7)
4 Open reverse, perhaps. (4)
5 The destroyer "Leopard"? (7)
6 The professional's name for what is seen with 8. (5)
7 A major part in "Life With Father?" (6)
8 A sight of oil has to be refined here! (4,2)
13 Wallace's bleeders, according to the poet. (5)
16 It's no matter of import when the world organization gets firm. (9)
18 One who stays sounds as though he might fly! (6)
19 General increase. (7)
20 One certainly isn't right to be both a sort of cad and liar. (7)
21 In the frying pan, perhaps, with a certain miss. (6)
23 With the words reversed, it implies modern "drive" is tasteful. (5)
25 Miss-beliefs? (4)

SOLUTION TO PUZZLE NO. 623

ACROSS: 1 SATURDAY'S CHILD; 9 NEEDFUL; 10 RELAPSE; 11 ISAIAH; 12 TEXTILES; 14 NOTCHES; 17 NOSED; 19 REACTOR; 21 and 15 TUESDAY'S CHILD; 23 STROVE; 25 CHIANTI; 26 TONGUES; 27 THURSDAY'S CHILD. DOWN: 1 and 2 SINGING IN THE RAIN; 3 REFRACTED; 4 ALLY; 5 SCREEN STAR; 6 HELOT; 7 LAPILLI; 8 WENS; 13 WHIRLYBIRD; 15 CATATONIC; 16 DIGRESSED; 18 SWEDISH; 20 RIO MUNI; 21 TUCK; 22 DONOR; 24 STAY.

Readers are invited to send for a free copy of Mr. Lewis's "ground rules." Address requests to Puzzle Dept., The Nation, 333 Sixth Avenue, New York 14, New York

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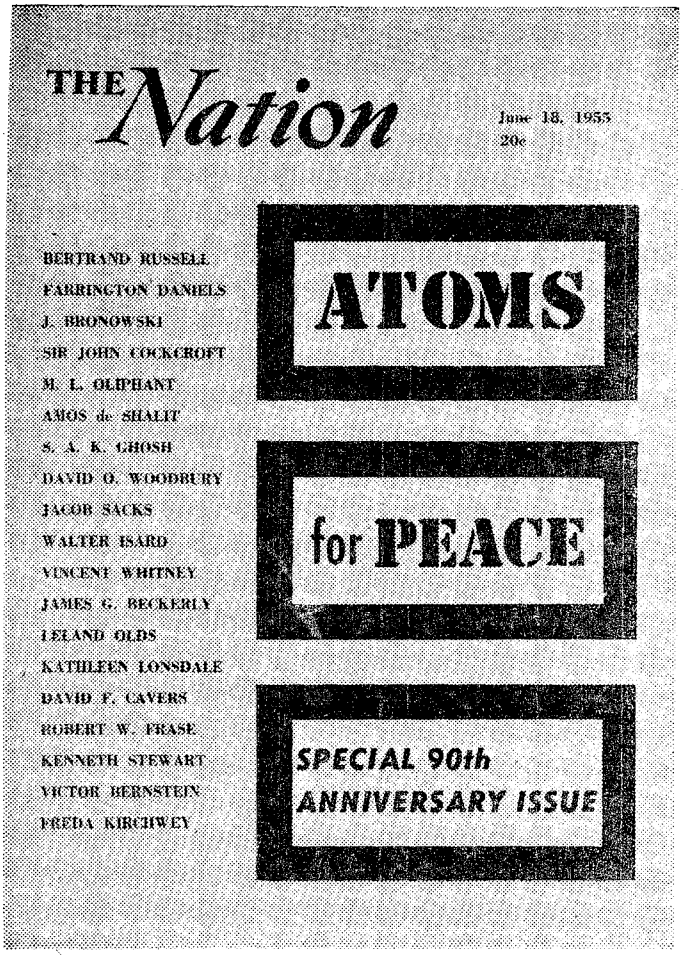

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